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THE VARIETIES OF ANKYLOSIS BY BONE IN DIFFERENT PARTS OF THE SKELETON;

AND

UNIVERSAL BONY ANKYLOSIS, OR ARTHRITIS OSSIFICANS.

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(Plates XXIX. and XXX.)

Before giving an account of my researches into the subject of bony ankylosis in different parts of the skeleton, I propose to give a brief historical review of our knowledge up to the present time.

We find that Hippocrates (1) makes special reference to fixation of the elbow-joint after dislocations, and that he gives directions how to place the arm in the best position after the reduction of such an injury. He makes no mention of ankylosis following upon destructive disease of joints. Hence it is that the ankylosis, following upon fractures and fracture dislocations of joints, which is of such frequent occurrence, has been called the Ankylosis of the Greeks.

Galen (2) follows in the line of Hippocrates, and makes, so far as we can gather, no advance in the subject.

During the period that intervenes between the time of Galen and the revival of the study of anatomy no advance whatever was made in the knowledge of ankylosis nor, indeed, of any other scientific subject in connection with medicine.

Ambroise Paré (3) says hardly anything more than Hippocrates about the subject.

At the beginning of the eighteenth century, however, some years after the revival of the study of anatomy by dissection, and of physiology by experiment, we find that an interest was awakened in the subject of ankylosis, as indeed in the study of the nature of all diseases.

Bernard Connor (4) published in the *Philosophical Transactions*, in 1700, an account, accompanied by a sketch, of ankylosis of the bones of the trunk which he saw while travelling in France. This specimen is interesting, as it is, so far as I have been able to discover, the first of its kind ever noted and described, and doubtless it is illustrative of the ankylosis in elderly people and an extremely good one of its kind. Soon after this he published at Oxford a treatise entitled "De stupendo

Ossium Coalitu," based upon the same specimen that he had previously described in the *Philosophical Transactions.*

Soon after this a series of theses upon this subject appeared on the Continent.

In 1707 Müller ([5]) published a thesis entitled "Diss. de Ancylosi," Leyden. In 1743 Büchner's ([6]) thesis, "Diss. de Ancylosi," Erford, appeared.

From Heister's ([7]) Surgery, published in 1768, it may be gathered that even at this time much progress had not been made. He, however, refers, not only to the ankylosis after the fractures and dislocations (of the Greeks), but also to stiffness following upon complete and long rest and disease of the joints, which he says may be cured by suitable means.

After this, other theses appeared: one in 1774 by Paul ([8]), "Diss. de Ancylosi," Strasburg; another in 1783 by Van de Wympresse ([9]), "Diss. de Ancylosi Singulari"; and still another soon after in 1797 by Murray ([10]), "Diss. de Ancylosi," Upsala.

In 1783 Ed. Sandifort ([11]) published his "Exercitationes Academicæ," and in these he gives an account, which is well illustrated by figures, of ankylosis of the atlas to the occipital, of the cervical vertebræ to one another and to the skull, and of the temporo-maxillary joint on one side. He makes reference to Columbus as having previously described examples of ankylosis of the atlas to the occiput.

From this period until well into the nineteenth century nothing of note was published on ankylosis. In 1833, in the "Dict. des méd.," 2nd edition, Paris, there appeared an article by Cloquet ([12]) upon ankylosis. This is the first comprehensive account of the subject. This author not only refers to ankylosis, as it is seen in the joints of the limbs, but also as it is met with in the vertebral column in elderly persons. Cruveilhier ([13]) follows Cloquet, and adds but little.

In our own country, in the year 1833, Mr. Wickham ([14]), Winchester, a pupil of Sir Astley Cooper, published a work entitled "Practical Treatise on the Joints," in which there is a good account of ankylosis in its different clinical forms. Soon after, in 1843, Dr. Little ([15]), of the London Hospital, published a pamphlet on ankylosis or stiff joint, in which is given a fuller and better account of the different varieties of ankylosis as met with in the joints of the appendicular skeleton; in addition, he points out the manner in which such joints may be severally dealt with in practice. Since this time attention has been mainly centred upon the treatment of ankylosis in the appendicular skeleton, and this has been considerably advanced in France, in America, in Germany, and in this country. To this part of the subject I do not propose to refer.

Such is, briefly, the account of the history of the advance in our knowledge of ankylosis from the earliest times up to the present.

Ankylosis in one form or another, especially that in the limbs after accident, has, therefore, been known since the earliest days of

surgery, and the name doubtless was first applied to indicate a bent or crooked joint. Hence it is probable that the word ankylosis is derived from "*ἀγκύλος*," signifying crooked or bent, rather than from "*ἀγκύλη*," a thong for binding things together, a name that would probably only be suggested when the nature of the uniting medium became known.

The term ankylosis is at the present time, however, applied to any joint that is fixed. If the cause of the fixation be in the tissue around, or in the external ligaments of the joint, it is said to be *false* ankylosis; if due to the union of the articular ends of the bones, whether by fibrous or bony tissue, it is said to be *true* ankylosis.

The forms of *true* ankylosis are subdivided according to the nature of the uniting medium into (1) *fibrous* and (2) *osseous*. These different forms of ankylosis are frequently met with, and the above classification serves well for clinical purposes.

Howard Marsh ([16]), in a recent paper on some rare forms of bony ankylosis, has made the suggestion that the osseous forms should be subdivided into two classes—(1) the *reparative* and (2) the *degenerative*. The difficulty in adopting such a subdivision of osseous ankylosis, it seems to me, is that there would arise an ambiguity in the use of the term *degenerative*, which may be applied equally well to a *function* as to a *process*.

In this paper it is my intention to study the processes by means of which bony ankylosis of joints takes place, and the conditions under which it occurs. Accordingly, ankylosis will be considered as it is met with (1) under natural conditions in vertebrates, and (2) under morbid conditions in man.

We shall find, for example, that in different groups of animals, vertebræ, which are in other groups free and movable, are fixed and immovable throughout life. In some of these groups of animals we may see and study the processes by means of which these separate bones become fused together, and to some extent see the conditions under which such ankylosis occurs; and such a study may and indeed does, help in the elucidation of the conditions, often obscure enough, under which morbid ankylosis takes place in man. These processes of ankylosis, whether under natural or morbid conditions, are well illustrated both in the axial and in the appendicular parts of the skeleton; and though each part is affected in precisely the same way, yet it will be convenient to consider the axial skeleton first and the appendicular last. In each part I propose to study the ankylosis that occurs in it under the following headings, which form the classification I shall adopt throughout the paper:—

BONY ANKYLOSIS.

I. Natural Ankylosis.
II. Morbid Ankylosis.
1. Congenital or pre-natal.
2. Post-natal.

THE AXIAL SKELETON.

There is perhaps no part of the skeleton that is so frequently the seat of bony ankylosis and that illustrates so well the different varieties of this condition as the spinal column. In this column the different bones are held together in diverse ways. The bodies of the vertebræ are united by means of an intervening disc of fibro-cartilage, and the neural arches are connected by means of (1) synovial joints between the articular processes; (2) by a strong yellow elastic ligament—the *ligamentum subflavum*—extending between the adjacent borders of the laminae; and (3) by fibrous ligaments extending between the tips of adjacent spines. Besides, the atlas and axis are united by synovial joints, as are the lateral masses of the atlas and the occipital condyles. In the cranium, moreover, the separate bones are connected either by a layer of dense white fibrous tissue, as between the flat bones of the vault, or by a thick layer of hyaline cartilages, as between the three elements—basi-occipital, post- and pre-sphenoids—in the basis cranii. We have therefore in the vertebral column and its continuation, the skull, several kinds of joints, each of which under certain circumstances is liable to become osseously ankylosed.

Bony ankylosis of the vertebræ occurs, however, as a normal process in certain parts of the column in man and in many animals in the vertebrate series. For example, in man, the sacral vertebræ unite or fuse together soon after puberty in their bodies, lateral parts, and laminæ; in the coccyx most of the separate elements unite into one mass or column of bone at and after the middle period of life; and the separate elements, each of which probably represents several fused bodies of vertebræ, in the base of the skull, also unite with one another, the pre- with the post-sphenoid early in life, and the post-sphenoid with the basi-occipital at or after puberty.

In some animals this same tendency to ankylosis of the vertebræ is still more marked, for in the porpoise (*Phocæna communis*) the cervical vertebræ (1–6) are fused in their bodies, laminæ, and spines; and in the right whales and other animals, which will be mentioned later, a similar fusion of cervical vertebræ may be seen. In the armadillos the sacrum consists of eight or more fused vertebræ, the hinder ones being rigidly held together by ossification of the great sacro-sciatic ligaments on either side.

The following classification already given in outline will be herein adopted:—

I. NORMAL.

(*a*) In the basis cranii.
(*b*) In the cervical region.
(*c*) In the dorsal and lumbar regions.
(*d*) In the sacral regions.

II. PATHOLOGICAL OR MORBID.

1. Congenital or Pre-Natal.

(*a*) In basis cranii.
(*b*) In cervical vertebræ.
(*c*) In dorsal vertebræ, etc.
(*d*) In the sacral and coccygeal regions.

2. Post-Natal.

(*a*) In the vertebral column.
(*b*) After injury.
(*c*) In tubercular and other allied diseases.
(*d*) In lateral curvature.

I. Normal Ankylosis by Bone.

(*a*) *In the Basis Cranii.*

If we leave out of consideration the ethmoid in the base of the skull there is left that portion, which is at least three-fourths of the whole, comprising the basi-occipital, post- and pre-sphenoids. In the embryo this portion of the skull is represented in the first place by a solid rod of hyaline cartilage which results from fusion of the *trabeculæ cranii*, and in which three separate centres of ossification make their appearance; *one* in the hinder part to form the permanent basi-occipital; a *second* in the front portion to form the pre-sphenoid of many animals and the anterior half of the body of the sphenoid in man; and a *third* in the middle to form the post-sphenoid or hinder half of the body of the human sphenoid bone. Thus there arise three centres or nuclei of ossification in the primitive cartilage, forming what is known as the basis cranii; and these three nuclei may be seen constituting three separate bones in a child at birth. Soon, however, the anterior and middle nuclei join together to form a single bone, the body of the sphenoid, ossification extending through the line or plate of cartilage from one nucleus to the other. This fusion does not take place early in other vertebrates, unless it be in the chimpanzee, in which animal the skull more nearly than that of any other animal approaches that of man, or, in other words, in which the relation between the extreme antero-posterior and the vertical measurement of the cranial cavity more nearly corresponds to that of man.

For example, in a specimen of the skull of a horse,[1] which was judged to be several years of age, the post- and pre-sphenoid bones are only united for a very short distance above and below, but not in the middle, and the basi-occipital is not at all united to the post-sphenoid. It is the same in dogs; all these bones remaining separated until the animal begins to get old, when the synchondroses tend to become obliterated and the different bones in part unite. Furthermore, in

[1] The comparative anatomy specimens referred to in this paper are all in the Museum of Zoology in Cambridge University.

the macacus ape, judged to be at least seven years of age, the post- and pre-sphenoid elements are only united at their upper and lower margins. A similar condition of these bones may be seen in the skull of *Cynocephalus babouin*; but in the chimpanzee (*Troglodytes niger*), the post- and pre-sphenoids are firmly and well fused together, though the synchondrosis between the basi-occipital and the post-sphenoid remains cartilaginous and unossified.

In by far the greater number of vertebrates the cranial cavity extends directly forward, and the face is also carried directly or almost directly forward. In man, however, the cranial base is foreshortened, and the face is almost entirely under cover of the skull. This foreshortening of the base of the skull is brought about by the early fusion of the two most anterior osseous nuclei in the cartilaginous base, the fusion taking place at or soon after birth in the human subject, and it may be so in the chimpanzee, but not until a much later period, if at all, in other and lower vertebrates.

(*b*) *In the Cervical Region.*

Though the cervical vertebræ in man are normally free, yet in a few of the lower animals they are naturally more or less ankylosed with one another. For example, in the right whales fusion of the cervical vertebræ is almost a characteristic feature. In one specimen, *Globiceps melas*, the first, second, third, and fourth, cervical vertebræ are fused by their bodies, by their laminæ, and by their stunted spines; in addition, the laminæ of the fifth cervical vertebræ are ankylosed to those of the fourth, though the bodies are quite free. Where the bodies and laminæ are fused, the external surfaces of the bodies are very uneven, and slightly spiculated from the formation of new periosteal bone. In another specimen (*Balæna mysticetus*), which has been mesially divided, the bodies of first, second, third, fourth, and fifth vertebræ are completely fused; the arch of the first or atlas is free, but the arches of the second, third, fourth, fifth, sixth, and seventh are quite ankylosed. There is partial fusion between the bodies of the fifth and sixth, especially at the periphery, the joint cavity being still traceable near the middle; the body of the sixth and seventh are, on the contrary, fused in the middle only, the peripheral part of the joint cavity being still free. On the fore-parts of the bodies of these vertebræ there is some new formation of periosteal bone. In a specimen of porpoise (*Phocena communis*), the first six cervical vertebræ are fused in their bodies, laminæ, and spines, and there is much spiculated new periosteal bone on the anterior surfaces of the bodies of these ankylosed vertebræ (see Fig. 1).

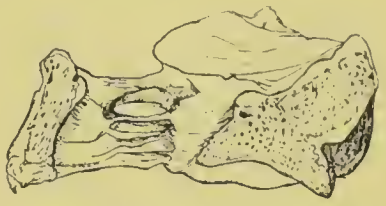

Fig. 1.—Mesial antero-posterior section of cervical vertebræ of the common porpoise.

In the armadillos the ankylosis of the cervical vertebræ is not

nearly so extensive, it being limited to two or three vertebræ. In one specimen (*Dasypus peba*), the second, third, and fourth cervical vertebræ are fused by their laminæ and spines, the arch of the first, or atlas vertebra remaining quite free. The bodies of these vertebræ remain distinct. In another specimen (*Priodontes gigas*), the second and third cervical vertebræ are fused by their bodies, laminæ, and spines, the remaining cervical vertebræ being free. Besides, there is among the Rodents a single species in which this ankylosis occurs. It is in the Jerboa. In the *Dipas agyptus*, the second, third, fourth, fifth, and sixth cervical vertebræ are fused together by their bodies, laminæ, and spines, the first, or atlas vertebra remaining free and distinct.

In these instances the ankylosis takes place, not only between the bodies of the individual vertebræ, but also between the articular processes, laminæ, and the spines where present; the fusion of vertebra to vertebra being more or less complete.

We may suppose that in the cervical region in the right whales and common porpoises the ankylosis takes place in one of three ways, until definite information is obtained. (1) By a process resembling that which takes place to form each element in the basis cranii, each segment being now generally regarded by morphologists as made up of several centra early fused together; (2) by a process identical with that which will be immediately described in the sacrum of the common fowl, where the centra are merely separated by a thin layer of hyaline cartilage; and (3) a process similar to that which often takes place between the vertebræ in elderly people, or to that found in the disease to be afterwards described under the name of Arthritis ossificans. Doubtless the manner in which this natural form of ankylosis takes place could be observed in the common porpoise, of which specimens of different ages may, I presume, be obtained without much difficulty.

(*c*) *In the Dorsal Region.*

Just as in one group or in part of a group of vertebrates, the cervical vertebræ are more or less completely fused or ankylosed with one another, so in another group the dorsal and lumbar vertebræ are either partially or completely fused with one another. This is the case in the Chelonia, in which class of animals the dorsal and the lumbar vertebræ are intimately connected by their neural arches with the under surface of the superjacent carapace. In consequence of this fusion of the neural arches with the carapace, the vertebræ become fixed, and no movement between them is possible. But although the neural arches are thus fixed with the carapace, and the dorsal and lumbar spine is rigid, yet the bodies (centra) remain separate from one another for a considerable time. Ultimately, however, they also may become fused with one another by the growth of bone from the

margin of one body to that of another, and this growth may encroach upon the intervertebral disc. This takes place quite early in some species, but, so far as I have been able to discover by an examination of a few collections, this would seem to be the exception rather than the rule. In a specimen of *Testudo elephantopus* fusion of the bodies of the vertebræ of the dorso-lumbar spine is quite complete.

(*d*) *In the Sacral Region.*

The number of vertebræ that fuse together to form the sacrum varies much in different groups of animals. In reptiles the pelvic girdle may only articulate with one, but more commonly with two, vertebræ. In birds and in mammals the sacrum consists of several vertebræ fused together. In the former the fusion is so complete that in the adult common fowl there is no trace of separate vertebræ, but simply a solid continuous column of cancellous bone which represents many (17) vertebræ; whereas in mammals the vertebræ which form the sacrum, though fused in their neural arches, are in most instances only incompletely fused in their bodies. In man the sacrum consists of five vertebræ, of which three only articulate with the ilium. In the ant-eaters (armadillos) the sacrum consists of eight or more vertebræ, the anterior ones being ankylosed to the ilium and the hinder ones to the ossified great sciatic ligaments. In order to investigate the processes by means of which ankylosis takes place between the several divisions of the sacrum, I will describe in detail the changes I have observed (1) in the sacrum of the bird (common fowl); (2) in that of the human subject; and (3) in that of the pig.

The sacrum in the common fowl.—In the sacrum of the common fowl the process of ankylosis differs from that seen in the sacrum of man in several respects, as will be immediately shown.

In the full-grown common fowl the sacrum is one single piece of bone, showing no signs, either externally or in mesial longitudinal sections, of being formed by the fusion of many segments or vertebræ. And except that small holes exist for the exit of each pair of nerves, the portion that corresponds to the bodies of the vertebræ is a rod of bone with an external thin layer of dense bone and an interior that is mainly composed of large cancellous spaces. If, however, a chicken, say 7 to 8 weeks old, be examined, the same bone is found to be made up of several segments (17) of cancellous bone united to one another by thin layers of hyaline cartilage (see Fig. 2).

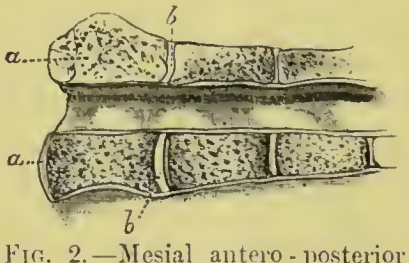

Fig. 2.—Mesial antero-posterior section of first three vertebræ of sacrum of common fowl, 7–8 weeks old. *a*, body of vertebræ; *b*, plate of hyaline cartilage between bodies. (Nat. size.)

In none of these cartilaginous septa are there any signs of the fibro-cartilaginous substance (disc) or of the soft pulp which frequently

(remains of notochord) occupies the middle of the intervertebral disc in other animals. The intervening cartilage is not transformed into fibro-cartilage, nor does it become split to form a joint cavity; and the ossification in the nuclei for the bodies gradually extends into it, backwards from the nucleus in front and forwards from the nucleus behind until the intervening plate of hyaline cartilage is quite absorbed and replaced by bone. This extension of the formation of bone into the intervening layer of cartilage takes place slowly, and in consequence the stages in the process cannot be well observed.

Though the process of ossification is slow, yet it is precisely the same in nature, only on a much smaller scale, as that which takes place in the epiphyseal cartilage of a long bone. In short, the growth is of a stunted character. This condition, it will be remembered, closely corresponds, if it is not identical, with that which takes place in the basis cranii, where there is first formed a bar of cartilage by the fusion of two rods (trabeculæ cranii) lying side by side, in which three separate nuclei of ossification arise, the intervening substance remaining in the condition of hyaline cartilage until it is completely replaced by bone and the bony juncture between the separate elements is established. Although the sacrum of a young fowl appears as if it had been laid down from the beginning in the form of a rod of cartilage in which several centres of ossification had arisen, yet it is pretty certain that this part of the column undergoes in early embryonic life changes similar to those that occur, say, in the cervical region. With this difference, however, the natural differentiation is permanent in the cervical region and transitory in the sacral.

The sacrum in man.—In man, on the contrary, the sacrum is, up to puberty, not only divided into its proper number of segments, but the segments corresponding to the centra, which are in the young composed of hyaline cartilage containing bony nuclei, are separated from one another by a disc of fibro-cartilage similar in every respect to that which forms between each of the dorsal and of other un-ankylosed, or free vertebræ. Thus the sacrum, though its several elements are ankylosed by bone in the adult, is developed in exactly the same manner as the other and un-ankylosed vertebræ. Up to the time of puberty the centra of the sacrum remain distinct from one another, being separated by thick, well developed intervertebral discs. After puberty, however, fusion of the different sacral centra begins to take place. It begins first in the discs between the lower segments and gradually extends upwards, the first and second centra being the last to unite. The process is very slow, and in consequence it takes years before these parts (centra) of the sacrum are firmly united to one another by bone, or ankylosed. In the majority of instances the margins of the articular surfaces grow towards and fuse with one another, replacing the outermost part of the intervertebral disc. This process extends centrally at the expense of the fibro-cartilaginous disc,

until it replaces the disc completely, and unites the two bodies in such a manner that no trace of the position of the intervertebral disc is left behind (see Fig. 3). In addition, bone may sometimes begin to grow from the articular surfaces of one or other or of both bodies, and gradually invade the disc, and in time extend through meeting and coalescing with a similar growth of bone from the surface of the opposed centrum. In one specimen I have before me, these two modes of ankylosis are well seen.

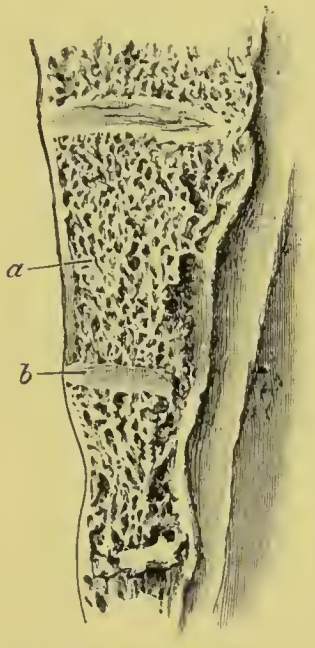

FIG. 3.—Mesial antero-posterior section of part of human sacrum (adult). *a*, body of vertebræ; *b*, intervertebral disc. (Nat. size.)

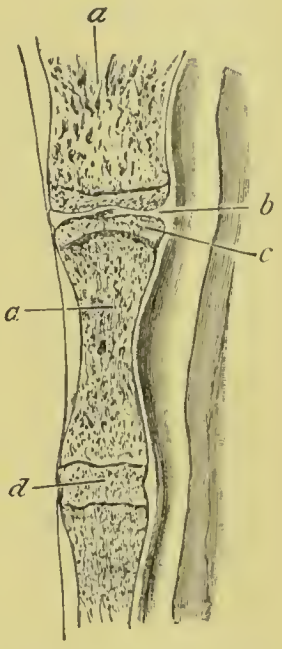

FIG. 4.—Mesial antero-posterior section of part of sacrum of a young pig. *a*, body of vertebræ; *b*, intervertebral disc; *c*, epiphysis; *d*, adjacent epiphysis fused.

The sacrum of the pig.—The mode in which the separate elements of the sacrum in the pig become united would seem to be intermediate between that which occurs in man and that which is found in the common fowl. If the sacrum of a pig that is not fully grown be examined, it will be seen that the intervertebral discs are absent, and are replaced by a plate of bone, which is formed not by the conversion of the disc itself into bone, as would appear at first sight, but by the fusion of two adjacent epiphyseal plates of bone across the disc, the two epiphyses uniting to form a single bone which later becomes fused both with the body in front and with that behind. Lastly, the cartilaginous plates which separate the epiphyses from the centra of the vertebræ disappear, and then the sacrum, which consists of four vertebral segments, forms a single piece of bone (see Fig. 4). In a newly-born pig the bodies of the vertebræ of the sacrum are united by well-formed intervertebral

discs, as, for instance, in the human subject at birth; but after the appearance of the epiphyseal nuclei of ossification, the process of bone-formation soon extends through this disc, and the fusion of two adjacent epiphyses takes place. In order to illustrate the process of ossification that takes place, I will describe a specimen taken from a young pig. Between the two layers of epiphyseal cartilages of neighbouring bodies there is a thin plate of bone, partially separated into two equal halves by a thin layer of fibro-cartilage, the representative of the intervertebral disc. Each plate of bone, which is cancellous in structure, is thus bordered on one side by the epiphyseal plate of cartilage, and on the other by the intervertebral disc. This intervertebral disc is composed at the periphery of fibro-cartilage, with bundles of fibres running in different directions, but the middle or central portion consists of hyaline cartilage, the matrix of which is in places infiltrated with granules of calcareous salts; in this respect it differs from the central portion of the intervertebral disc in man, which, as is well known, is composed of soft pulp. The bone next to the disc is composed of a thin layer of dense, compact tissue, with thick trabeculæ and few small spaces which are filled with blood vessels and numerous connective tissue cells; whereas at a little distance the bone trabeculæ are thin, the spaces large and chiefly occupied with fat cells. As has been said above, the disc becomes converted into bone before the cessation of growth of the vertebræ, and also before the disappearance of the epiphyseal line of cartilage. Near the periphery where the disc is represented by fibro-cartilage, the cells in its matrix are large and granular, but they never accumulate in one space, and the matrix loses its fibrillar character, becoming either homogeneous or granular. Into this altered matrix a small bud-like process consisting of a blood vessel with accompanying connective tissue cells from the subjacent bone projects; several such projections may be seen. How the tissue of the disc becomes removed so as to give place to the growing bud from the bone cannot be made out; but we can infer, from analogy to similar processes in other parts of the body, that the absorption of the altered substance of the disc takes place in virtue of the activity of the cells in the invading bud. Near the centre of the disc, where it is composed of hyaline cartilage, the cartilage cells show some tendency to accumulate in small groups, but there is no distinct arrangement of them into long spaces as is seen in a growing long bone at the epiphyseal plate. Here as in the peripheral parts many bud-like processes project from the adjacent bone into the disc. By this means doubtless the disc, in part fibro-cartilaginous and in part hyaline, becomes gradually and early replaced by bone.

Remarks.—We have already seen that in different parts of the axial skeleton bony ankylosis takes place naturally; and especially is

this the case in different parts or divisions of the spinal column. In the basis cranii the time at which fusion of the separate elements takes place seems to depend in the main upon the form and size of the cranial cavity, and upon the relation of the face to the skull. For in those animals in which the brain case is not large, is much greater in length than in depth, and in which the face is a prolongation forward of the skull, there seems but little tendency to fusion of the three separate elements of the base. But as the brain becomes more highly developed and greater in bulk, and the face tends to become more and more under cover of the skull proper, we find that the pre- and post-sphenoid elements show a tendency to fuse with one another: and in man, in whom the length of the base of the skull bears the least proportion to the depth of its cavity, these two elements unite soon after birth, and their union with the basi-occipital takes place at or soon after the period of puberty. We shall see in what immediately follows that this fusion may and does not unfrequently occur before birth, and when it does so there is associated with it defective development of the brain resulting in idiocy.

In the cervical vertebræ fusion would seem to occur when the neck is practically obliterated, as in the right whales and porpoises, the contraction of the neck doing away with movement, and leading to compression of several cervical vertebræ. In these animals it will be noted that the atlas retains its articulations with the skull, and that there is, therefore, free movement in a vertical plane between the skull and the spinal column. There is, however, one point of interest in connection with these and that is, How do they ankylose? This must at present remain unanswered. In the ant-eaters it is common to find the second and third, and it may be the fourth cervical vertebræ ankylosed by bone to one another. In these animals it will be noticed that the spine of the second vertebra is uncommonly large, and forms an expanded flat piece of bone. The enlargement of this spine is, I presume, for the attachment of a powerful neck muscle: and I would venture to think, though without any direct evidence, that the fusion of one or more vertebræ to it, namely, those next behind it, is for the purpose of affording additional area, or surface, and greater strength for the attachment of the powerful neck muscles.

Accordingly, in the neck, it is reasonable to suppose that the natural fusion of the vertebræ takes place in consequence of (1) compression and immobility, and (2) to afford additional strength for powerful neck muscles.

In both dorsal and sacral regions ankylosis is doubtless determined primarily by the fixation of the vertebræ. In the tortoise the vertebræ in their neural arches, and to a less extent in their bodies, become joined to one another because they are rigid and immovable, being held in their position by firm attachment to the carapace.

In the sacral region the vertebræ are rigid and immovable from

their fusion with the ossa innominata, and from the staying influence of the sacro-sciatic ligaments, be they composed of fibrous tissue as in man or of bone as in the ant-eaters and sloths. Here, clearly, fixation determines the development of ankylosis between the several segments of the sacrum. The manner in which this ankylosis is brought about has already been fully given.

From this we may conclude by saying that (1) in case of compression the vertebræ are liable to become fused or ankylosed together; (2) when there is necessity for additional strength without movement the vertebræ tend to unite; (3) where the vertebræ are kept fixed, rigid, and immovable, they tend to unite early or late with one another by bone so as to constitute one single piece.

II. Pathological or Morbid Ankylosis.

1. Congenital or Pre-Natal Ankylosis.

Pre-natal fusion of bones, which are otherwise separate under natural conditions, is of not uncommon occurrence. In the appendicular skeleton this premature and unnatural fusion of the separate bones is comparatively rare, but in the vertebral column it is not unfrequently met with. For convenience' sake I will describe the congenital ankylosis according to the natural divisions of the axial skeleton, namely, the cranium, cervical, dorsal, lumbar, sacral, and coccygeal regions of the spinal column, as has been done with the normal or natural ankylosis.

(*a*) *Ankylosis in the Base of the Skull.*

It has been already pointed out that the basis cranii is composed of three segments, one in front of the other. They are from behind forwards, the basi-occipital, the post-sphenoid and the pre-sphenoid. In the majority of the lower animals these segments remain distinct from one another until long after birth, if they do not always remain so; but in man the two foremost segments, namely, the post- and the pre-sphenoid, though separate at birth, soon fuse together to form the body of the sphenoid bone. It not unfrequently happens, however, that during some disturbance in the fœtus, there occurs, together with other important changes, premature fusion of two or of all three segments in the basis cranii. For example, in the anencephalous fœtus, a comparatively common congenital abnormality, the two foremost segments, the post- and pre-sphenoid bones, are completely united before birth; and in the condition known as congenital rickets (short-limbed, pero-melic fœtus), all the three segments are liable to be ankylosed to one another forming a single bone, the os tribasilare, even some time before birth. This was first pointed out by Virchow ([16]).

If we compare the basis cranii of a fœtus at full term with that

(1) of an anencephalous fœtus, (2) of a fœtus with congenital rickets, this point will be made clear. In a fœtus at full term the three elements constituting the base of the skull are separated from one another by a plate or layer of hyaline cartilage. The plate between the pre- and post-sphenoid soon disappears, but that between the post-sphenoid and the basi-occipital does not disappear until about the twenty-first year.

FIG. 5.—Mesial antero-posterior section through the basis cranii of an anencephalous fœtus. *a*, pre-sphenoid; *b*, post-sphenoid; *c*, basi-occipital. (Natural size.)

In an anencephalous fœtus the pre- and post-sphenoid are invariably united at the time of birth (see Fig. 5), the cartilaginous plate having quite disappeared and its place been taken by dense bone, but the post-sphenoid and basi-occipital still remain separated by a layer of hyaline cartilage from which the further growth of the basis cranii would take place. The fusion of the two elements which form the body of the sphenoid bone takes place some short time, at any rate, before birth, for the united bones are shorter from before backwards, and indeed to some extent in depth, than the separate bones in the fœtus at full term. For example, in a specimen of anencephalous fœtus at full term, the post- and pre-sphenoids together measured in length 14·5 mm., whereas the same bones in a small fœtus at full term measured 16 mm., and in a large fœtus, 20 mm. In addition to premature obliteration of the cartilaginous plate between pre- and post-sphenoids, there is some deficiency in the growth of the basi-occipital, for this bone is also shorter and smaller than it is in a fœtus at full term, measuring in a specimen of fœtus at full term 13 mm. in length, but only 10·5 mm. in an anencephalic monster. In a pero-melie (short-limbed, congenital rickets, etc.) fœtus the three separate bones in the basis cranii may be completely fused as in the specimen described by Virchow ([17]), or the pre- and post-sphenoids only may be united, the cartilage between the post-sphenoid and the basi-occipital remaining unossified. In the two specimens of congenital rickets in the Pathological Museum of the University of Cambridge the condition of the bones in the basis cranii is similar to that invariably met with in anencephalic fœtuses, and there is distinct shortening which indicates that the union of the pre- and post-sphenoids took place some time before birth.

This premature obliteration of the cartilaginous plates in the basis cranii is therefore accompanied to an appreciable extent by the cessation of growth. This premature fusion also takes place in idiots to a greater or less degree. For example, the length of an ordinary skull from the anterior margin of the foramen magnum to the fronto-nasal suture is from 97–100 mm., whereas in three typical specimens of idiots' skulls in the museum the measurements are 90, 94, and 88 mm. In one of these skulls, from an idiot æt. 19 years, the cartilage plate between

the basi-occipital and the post-sphenoid has quite disappeared, the two bones being fused by cancellous tissue one with the other. In another specimen removed from an idiot of the same age the plate of cartilage has become transformed into bone, with the exception of one-sixth of an inch at the upper part, and a short extent at the lower, the plate of bone, representing the cartilage, remaining distinct between the post-sphenoid on one side and the basi-occipital on the other, as will be seen to occur in the vertebral column.

When reference was made to the natural process of ankylosis in the base of the skull it was pointed out that in those animals in which the cranial cavity was long in proportion to its height, all the three bones in the base usually remain distinct from one another for many years, if not throughout the life of the animal; whereas, in those in which the length is less in proportion to the height, as in chimpanzee and in man, the pre- and post-sphenoids have a tendency to unite early, and the post-sphenoid may unite, as in man, with the basi-occipital on the attainment of adult age. It may be assumed, therefore, that as the brain increases in its size the skull becomes deeper in proportion to its length, and owing to the fact that the cerebral hemispheres enlarge upwards and backwards over the cerebellum there is no necessity for an increase in length of the base but merely in the growth of the vault. Hence the early and even total obliteration of the synchondroses of the base of the skull in man and, may be, in the chimpanzee. In man, however, this tendency to early obliteration of the synchondroses in the basis cranii may be so influenced by obscure diseased conditions that two or all the three bones may become prematurely united, the medium of growth (cartilage) disappearing. When this takes place the result is that there occurs defective development of the cerebrum, whether as a consequence or as a part of the same disease it would be difficult to determine.

(*b*) *In the Cervical Region.*

The cervical region is, so far as I have been able to discover, by far the most frequent seat of congenital fusion, or ankylosis of the different vertebræ; but this is not common, indeed, I should say that it is hardly known except in association with some congenital deformity of the skull, the usual one being that found in the anencephalous fœtus. In the anencephalous fœtus there is commonly found more or less extensive spina bifida, which may involve the cervical region only or, indeed, the whole length of the spinal column. In these cases there is usually eversion of the un-united neural arches which are often flattened and fused together; also not unfrequently some irregularity in the ossification of the bodies of the vertebræ. For example, the bodies, even at the time of birth, may be composed of two nuclei, or centres of ossification lying side by side, and occasionally one or more

vertebræ will only be represented by one such unilateral centre of ossification, this leading to a congenital deflection of the spinal column. Congenital fusion of the bodies of the vertebræ, although often referred to as a not uncommon occurrence by Rokitansky ([18]) and others, is, on the whole, rarely met with. There is a very good specimen illustrating this state of the bodies of the cervical vertebræ in an anencephalous fœtus in the Cambridge Pathological Museum, the description of which is as follows:—

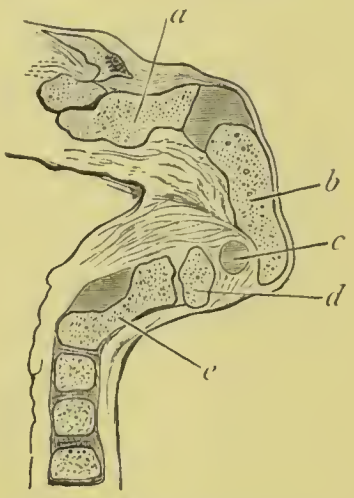

FIG. 6.—Mesial antero-posterior section of base of skull and cervical spine of an anencephalous fœtus with cervical spina bifida. *a*, sphenoid; *b*, basi-occipital; *c*, anterior arch of atlas; *d*, body of second vertebra; *e*, fused bodies of third, fourth, fifth, and sixth cervical vertebræ.

SPECIMEN 1 (No. 2013). *Anencephalous fœtus at full term with fusion of several cervical vertebræ.* —This anencephalous fœtus is of the usual type, and the deformity of the head is associated with more or less extensive cervical spina bifida. The bodies of the third, fourth, fifth, and sixth cervical vertebræ are fused together into one single piece of hyaline cartilage, in which is embedded a piece of bone, measuring only 12 mm. in depth from above downwards. There is no trace of division either externally or in section of the different pieces constituting the mass (see Fig. 6). The atlas is free, and so is the body of the second vertebra, or axis. The neural arches, which are turned outwards, as in spina bifida, are fused together, except in the pedicles, to allow for the exit of the nerves.

It accordingly will be observed that in the above specimen, not only are the neural arches of all the cervical vertebræ united with one another, but that the bodies of the third, fourth, fifth, and sixth are also united into one solid piece of cartilage containing a nucleus of bone. The bodies of the second and the seventh cervical vertebræ, though their everted neural arches are united with those adjacent to them, remain distinct, and are each separated from the nucleus representing the united bodies by fibro-cartilaginous discs.

We have here, I presume, a condition of vertebræ which resembles that seen in the basis cranii. The primitive column passes with great rapidity through its phases in development. The intervertebral discs disappear quickly, and the bodies which are cartilaginous fuse together into one solid piece, in which one or several nuclei of ossification appeared. If many nuclei arise they soon fuse owing to the absence of the fibro-cartilaginous discs, the natural barrier to growth of bone from one vertebra to another. It is, indeed, probable that the processes of differentiation that take place in the primitive vertebral column occur in these congenital ankyloses but that they are very transitory. If this view be adopted, congenital ankylosis would be comparable to the natural fusion that takes place in the separate elements of the basis cranii and, it may be, in the sacrum of the common fowl.

(*c*) *In the Dorsal Region.*

Congenital fusion of vertebræ in the dorsal region is extremely uncommon. There is a specimen in the Museum of an aneneephalous fœtus with spina bifida extending along nearly the whole length of the column in which in the mid-dorsal region the bodies of two adjacent vertebræ are fused with one another. In the Museum at Guy's Hospital there is a specimen, which is regarded as of congenital origin, of almost complete fusion and imperfect development of the bodies of the third, fourth, and fifth dorsal vertebræ in an adult female; in addition, the laminæ of the third and fourth, and the right transverse processes of the sixth and seventh cervical vertebræ are united.

(*d*) *In the Sacral and Coccygeal Regions.*

I have not succeeded in finding either record or examples of congenital fusion of the different elements composing the sacrum and coccyx.

Remarks.—Congenital ankylosis of vertebræ is, as I have said before, often referred to as of not unfrequent occurrence, but I find from the examination of pathological collections in different museums that it is comparatively unfrequent, if not very rare. I have already alluded to the congenital ankylosis of the separate elements in the base of the skull, and fusion of these three bones may occur, though it is more common to find premature fusion of the pre- and post-sphenoid elements only. In the vertebral column fusion of the laminæ in cases of spina bifida is common enough whether associated with the anencephalous state or not; but the fusion of the bodies of the vertebræ is very uncommon. The interesting feature of the specimen of congenital fusion of vertebræ above described is that the bodies of the greater number of the cervical vertebræ are represented by one piece of hyaline cartilage, in which there is a single nucleus of bone. There is in this no evidence that the portion of the spinal column ever underwent any differentiation into cartilaginous vertebræ and fibro-cartilaginous discs. It might, therefore, be assumed that the process of differentiation that naturally occurs in the course of development did not here take place. It must be remembered, however, that the early differentiation of the column into cartilaginous vertebræ and fibro-cartilaginous discs may have taken place, the latter undergoing rapid disappearance and leaving a rod of cartilage in which one or many centres of ossification would arise.

2. Post-Natal Bony Ankylosis.

In many joints in the trunk there seems to be a more or less natural tendency to ankylosis, which shows itself with advancing age.

It is well known that the vertebral column tends, with age, to become set in its curves, whether in the bent position from stooping at work, or straight as in the soldier; and, as it becomes set, the muscular power necessary to support it gradually and in due proportion diminishes, while the individual segments of the column become less and less movable upon one another, and at last immovable and ankylosed. Bony ankylosis between the different segments of the vertebral column also occurs under other conditions, such as after injuries, in lateral curvature, and after destructive disease, such, for example, as tuberculosis with and without suppuration. The majority of instances of bony ankylosis in the vertebral column, however, occur without any suppurative or other destructive disease in the joints; whereas, in the appendicular skeleton the reverse holds good, the majority of instances of bony ankylosis resulting from tuberculosis or such like disease with suppuration.

(*a*) *In the Vertebral Column.*

The spine in elderly people.—In man the spine during its development and growth undergoes many changes in its curvatures; and it is these curves that render the human column distinctive from that of all animals. In him alone the lumbar portion of the spine becomes strongly curved forwards so as to give a hollow in the region of the small of the back. In the human embryo, it will be remembered, the spine is first of all in the form of a general curve with its convexity dorsalwards, and as growth proceeds this convexity becomes less and less, until, at the time of birth, the column down to the sacrum is almost straight, the lumbo-sacral angle being, however, already well formed. After birth and up to the period of adolescence, the spine is ever endeavouring to acquire its proper curves; and in order to do so the muscles associated with it, chiefly the erectores spinæ on either side behind, maintain proper balance by throwing the dorsal region backwards and incurving the region of the loins. Up to adolescence there is a more or less constant effort exerted to develop these curves properly. Once they are formed they do not, however, become fixed and cease to require proper maintenance, but they are ever tending to change, any diminution in the muscular power of the erectores spinæ being soon followed by stooping, which, once established, tends to become worse and worse, for the muscles are thus placed at a greater and greater mechanical disadvantage. Throughout the period of active life the spine is usually maintained in its proper curves, but in elderly persons it is common, indeed if not usual, to find that stooping of a more or less pronounced degree takes place.

From the annexed curves (see Fig. 7) taken from the anterior surface of typical columns of elderly people, by means of a strip of lead, of which a tracing is made on paper, it may be seen that the spine acquires several different forms of curves. The commonest of all is an exaggeration

of the natural curve in the upper dorsal region, and the least common the one in which the spine becomes almost straight with the body bent near to the horizontal line at the hip joints. In one of the specimens the cervical, dorsal, and lumbar portions of the column form one curve with its convexity backwards, and in another the lumbar curve is exaggerated as well as the dorsal. With these alterations in the curves of the column the vertebræ are very liable to become united to one another in one of the several ways illustrated by the specimens to be immediately described. Such changes may or may not be dependent upon the changes in the curves coming on with age from diminution in the power of the muscles of the back. In some cases, however, it would appear pretty certain that bone-changes precede the alterations in the curves. Such cases are not unfrequently seen in elderly men who complain of deep, vague pains in the back, a condition usually regarded as lumbago without any better reason than that there is pain of an indefinite character in the back.[1]

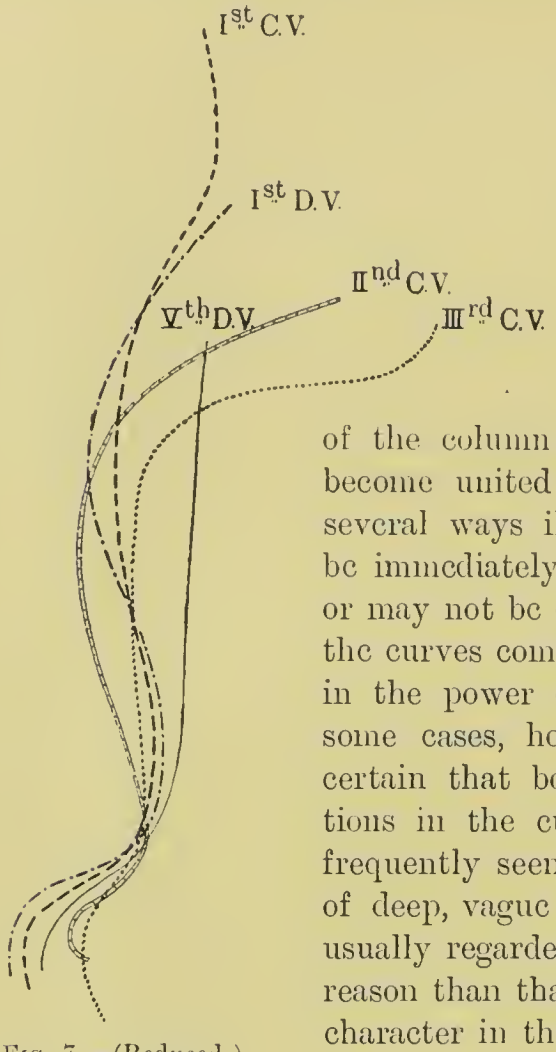

Fig. 7.—(Reduced.)

- - - - Adult Sp.
· - - - · Elderly Man.
——— Elderly Man.
Specimen 2017. R.C.S. Eng. Mus.
..... Old Man.

Cervical Region.

Although, as has been mentioned above, the cervical vertebræ are naturally ankylosed in the right whales, common porpoise, etc., yet in man, as in most vertebrates, each cervical vertebra is free, and the movement of this part of the column may be said to be of considerable range; and especially is the movement free between the skull and the atlas, and the atlas and the axis, the chief joints between them having synovial cavities. Nevertheless there is a great tendency in man to ankylosis between the atlas and the occiput, and the axis and the third cervical vertebræ, as will be presently pointed out.

Between the atlas and the occiput ankylosis may involve one or both occipito-atloid joints or both joints and one or both arches. The following specimens, which are in the Cambridge Anatomical Museum, and which were kindly placed at my disposal by Professor Macalister, illustrate very well the different forms that are met with.

[1] These cases are allied to the disease known as spondylitis deformans.

Specimen 3 (No. 176). *Romano-British skull, Hampden Hill.*—The atlas is ankylosed to the occipital bone. There is a complete bony union of the two occipito-atloid articulations, complete union by ossification of intervening ligament between the posterior arch and the hinder margin of the foramen magnum, but incomplete union between anterior arch and fore-part. There is also partial union by bone between the left transverse process of the atlas and the left lateral process of the occipital bone, and here the aperture for the vertebral artery is reduced to a little more than one-twelfth of an inch in diameter. In this specimen the fusion by ossification in ligaments and joints is almost complete, the atlas retaining its natural relation to the occiput.

Specimen 4 (No. 1033). *Peruvian skull; fusion of occiput and atlas at joints only.*—There is complete bony ankylosis of both occipito-atloid articulations, and there is some new bone at the articular margins of each joint as well as on both anterior and posterior atloid arches. The vertebra retains its normal relation and distance to the occiput.

Specimen 5 (No. 1464). *Ancient Egyptian; fusion of occiput and atlas at joints only.*—There is complete bony ankylosis of both occipito-atloid articulations, and there is much new bone around the margins of the joint surfaces. The arches are normal, and the atlas retains its natural relation and distance to the occiput.

Other cervical vertebræ are not unfrequently the seat of bony ankylosis, as is shown by the following specimens in the Cambridge Pathological Museum :—

Specimen 6 (No. 1899). *Fusion of articular processes of second and third cervical vertebræ.*—There is incomplete ankylosis by bone between the bodies of the second and third cervical vertebræ, mainly the result of the formation of bony outgrowths at the margin of the articular surfaces. There is complete ankylosis between the left, and an incomplete between the right, articular processes. No fusion of neural arches or of spines.

Specimen 8 (No. 1897). *Fusion of bodies, articular processes, laminæ and spines of second and third cervical vertebræ.*—There is complete bony ankylosis between the bodies, articular processes, laminæ and spines of the second and third cervical vertebræ, which retain their usual relation and distance to one another. In a vertical mesial section the bodies of the vertebræ are seen to be fused with one another at the periphery where the cancellous structure of the one is continuous with that of the other, the intervertebral disc having at that place completely disappeared. In the middle, however, the intervertebral space still exists; and here the body of each vertebra is limited by a thin articular limiting plate of bone as under normal conditions. The neural arches are also firmly united, the cancellous bone of the one being directly continuous with that of the other, the outer dense plate of bone at the adjacent margins having completely disappeared (see Fig. 8).

Fig. 8.—Mesial antero-posterior section of second and third cervical vertebræ. *a*, body of second vertebra; *b*, body of third vertebra; *c*, fused laminæ.

Specimen 9. *Fusion of the bodies of the second and third cervical vertebræ.*—The second and third cervical vertebræ are firmly united. The bodies, pedicles, laminæ, and spines are free and at the usual distance from one another; but the articular processes are fused, the left completely, the right

only partially. The adjacent margins of the left articular processes are outgrown and fused; in a transverse section there is no trace of a joint cavity, the two processes being continuous with one another through their cancellous interior. The margins of the right articular processes are similarly outgrown but not fused, and the joint surfaces are free, though rough and uneven, except at the innermost part. The right inferior articular process of the third is affected similarly to the other processes.

The Dorsal, Lumbar, and Sacral Regions.

Ossification of the Intervertebral Discs, Marginal Plates, and Fusion of Articular Processes and of Laminæ.

Specimen 10. *Pelvis with second, third, fourth, and fifth lumbar vertebræ from the dissecting-room (evidently from an old man).*—The bodies of the second, third, and fourth lumbar vertebræ are united in front and on each side, but not behind, by a thin plate of dense bone which bridges over from the articular margin of one vertebra to that of the other. This plate or bridge is incomplete between the marginal borders of the fourth and fifth lumbar and fifth lumbar and first sacral vertebræ. In mesial sections of the vertebræ the thin plates or bridges are seen to be composed of dense almost ivory-like bone, and further, the intervertebral discs are more or less completely transformed, without any diminution of their natural thickness, into distinct plates of cancellous bone. The intervertebral disc thus converted into bone retains its form and outline. The cancellous bone of which it is composed is defined above and below, that is, at its upper and lower surfaces by a thin but well-defined plate of dense bone, just as the centrum of each vertebra is defined; and there is a small fissure-like interval between the body and the disc which, in the recent state, was no doubt occupied by the remainder of the fibro-cartilaginous unossified disc. This appearance is very striking, for between the centre of the vertebræ there lies not a space which would, in the recent state, be occupied by a disc of fibro-cartilage, but a more or less complete and distinct disc of cancellous bone (see Fig. 9). The disc between the last lumbar and first sacral vertebræ, which is shown in the figure, is the one most completely converted into bone.

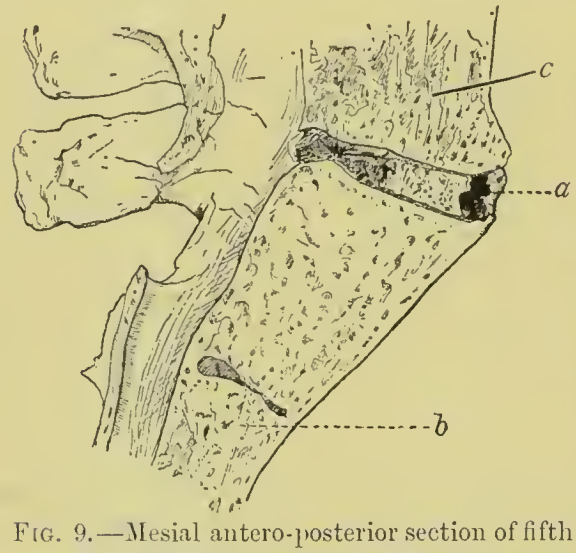

Fig. 9.—Mesial antero-posterior section of fifth lumbar and upper sacral vertebræ. *a*, ossified disc between fifth lumbar and first sacral vertebræ; *b*, sacrum; *c*, fifth lumbar vertebra.

The laminæ of the second, third, fourth, and fifth lumbar vertebræ are united, without any approximation of their opposed margins, by somewhat dense cancellous bone which is coarsely ridged from above downwards on both anterior and posterior surfaces. Thus the ligamenta subflava are wholly replaced by bone, and the laminæ are rigidly connected. The articular processes are also firmly united by coarse cancellous bone, the synovial joints having completely disappeared and been replaced by bone. The spinous processes are covered with numerous coarse spicules of bone, many of which doubtless run in the direction of the interspinous ligaments. The sacrum is firmly ankylosed to both iliac bones, not only by thick plates of dense bone

which extend in front from the alæ of the sacrum to the adjacent parts of the iliac bones and bridge as it were over the articulations, but also in part by the obliteration of the sacro-iliac joints themselves, by the growth of bone across the articulations, thus forming a partial synostosis of the bones.

Anterior Plate of Dense Bone bridging over Intervertebral Discs and Growth of Bone from Body of one Vertebræ to another, through the Intervertebral Discs.

Specimen 11. *Spine and pelvis of an old man; from the dissecting-room.* —This spine illustrates remarkably well the commonest curve in old age. It is strongly bent backwards in the mid-dorsal region, and there are other minor changes (compensatory) in the general curve of the spine.

The sixth, seventh, eighth, ninth, tenth, eleventh, and twelfth dorsal and first lumbar veretebræ are firmly united by bone. On the front of the bodies of the lower dorsal vertebræ there is a dense, continuous plate of bone, about one inch in width, which is firmly united to the front of the bodies, and which bridges over the intervertebral discs and thus firmly binds the several bodies together. On the sides of the bodies of the tenth, eleventh, and twelfth dorsal and first lumbar vertebræ there are thick buttresses of rather dense cancellous bone which have grown towards one another from opposite places on adjacent vertebræ and which span over the intervening discs. Similarly, buttresses of bone are seen in different degrees of formation on the lateral parts of the second, third, fourth, and fifth lumbar vertebræ. In mesial section of the lower dorsal vertebræ, the dense plate of bone on the anterior surface of the bodies is seen to be in places even one-third of an inch in thickness and, here and there, of almost ivory hardness. Owing to the backward curve, the anterior parts of the bodies of the vertebræ are closely approximated, and here the bone from adjacent vertebræ has grown across through the intervertebral disc so as to fuse the bodies together.

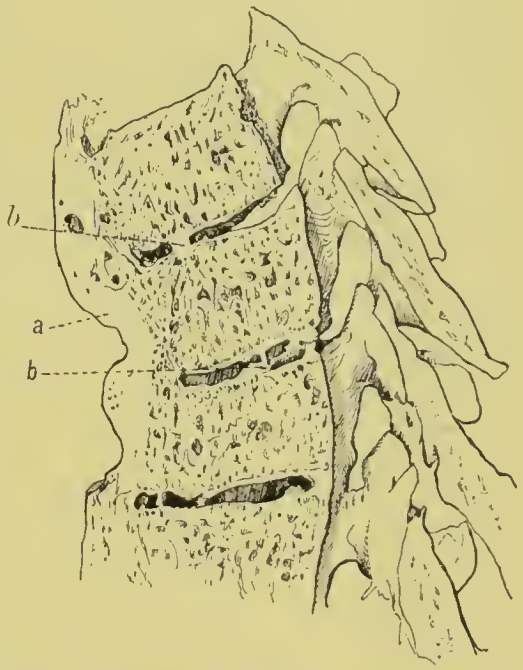

Fig. 10.—Mesial antero-posterior section of lower dorsal vertebræ. *a*, dense plate of bone in front of bodies; *b*, growth of bone from one body to another through the intervertebral disc.

In a few instances the posterior margins of the articular surfaces of the bodies have in like manner coalesced; and in one or two instances the bodies of adjacent vertebræ have grown together, thus completely obliterating the intervening intervertebral disc, and uniting two bodies into one solid bone (see Fig. 10). It is difficult to determine whether any of the intervertebral discs in this specimen have been independently converted into bone.

On the adjacent borders of the laminæ of the lower dorsal vertebræ there are numerous small coarse spicules of bone, but these have not grown sufficiently to unite adjacent laminæ. Neither the articular processes nor the spines are joined together by bone, each remaining, though their corresponding bodies are fixed together, natural and free. The sacrum is firmly united on each side to the iliac bones by a dense plate of bone in front of each articulation. The upper dorsal and the cervical vertebræ remain natural.

Well-developed Buttresses, some united, and some serrated and merely opposed.

Specimen 12 (No. 1904). *Seven lower dorsal lumbar vertebræ and pelvis from an elderly man.*—The spinal column is almost straight, the lumbar and the dorsal curves having quite disappeared. This represents an unusual though not a very uncommon change in the curve of the spine in elderly people. The fifth, sixth, seventh, eighth, and ninth dorsal vertebræ are united on the right sides of their bodies by a continuous, thick, wavy, and dense plate of bone, which is freely incorporated with the bodies of the vertebræ, and which bridges over the intervals filled, in the recent state, by the intervertebral discs of fibro-cartilage. This plate was evidently made up of portions corresponding to the bodies of each vertebra, which portions grew together over the intervertebral space and became fused along a sinuous line, often like a suture in the vault of the skull, and of which traces may, here and there, be seen. The tenth, eleventh, and twelfth dorsal and the first, second, third, fourth, and fifth lumbar vertebræ are united on the right sides of their bodies by thick massive buttresses of bone which extend across the intervertebral disc-interval and form uniting bridges; the tenth, eleventh, and twelfth dorsal and first lumbar vertebræ are similarly united by bridges of bone on the left side of their bodies. The laminæ, articular processes, and spines remain natural. The sacrum is united on each side to the iliac bones by a thick dense plate of bone extending from one to another in front of the joint. The acetabula are much changed from osteo-arthritis.

Specimen 13 (No. 1901a). *Buttresses of dense bone not yet united, bridging over the intervertebral discs; seven lower dorsal and one lumbar vertebræ.*—On the right side of the bodies of the sixth, seventh, eighth, ninth, and tenth dorsal vertebræ are thick, dense plates of bone, about half an inch in width, which are firmly incorporated with the bodies of the vertebræ, and which meet one another over the space occupied in the recent state by the intervertebral disc. The line of junction of these plates is situated near the middle of the disc and is sinuous, the sinuosities of the one fitting into those of the other in such a manner that when they are approximated no movements of the vertebræ upon one another is possible. The laminæ, articular processes, and spines are free, and show no signs of bony growths on their surfaces.

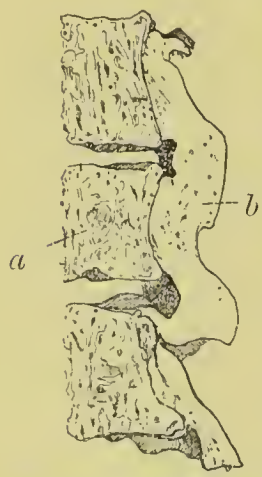

Fig. 11. — Section through portions of three dorsal vertebræ. *a*, body of vertebra; *b*, plate of dense bone joining vertebræ together.

The formation of plates of dense bone, bridging over from one vertebra to another, is remarkably well illustrated in the accompanying drawing, taken from a section of three dorsal vertebræ from another and similar specimen (No. 1901). The plate of bone is, as it were, soldered on to the surface of the vertebra (Fig. 11).

Before proceeding to consider the ossification of the ligaments, I would here briefly refer to the conditions to be observed in a recent specimen, where there are buttress-like growths as well as the marginal formation of new bone.

If a column in which there are numerous bony outgrowths be

taken in the fresh state and sawn so as to divide, longitudinally, such outgrowths, it will be seen that the intervertebral disc extends outwards between them (see Fig. 12). Gradually, as the outgrowths of bone grow towards one another, the extension, for it can be called nothing else, of the intervertebral disc disappears until at last the two buttresses are united, in other words, welded together.

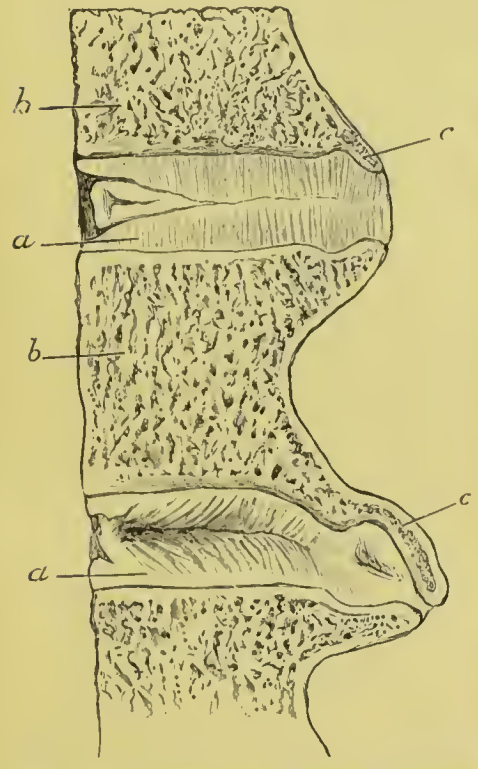

FIG. 12.—Section of a dorsal vertebra with portions of the adjacent vertebræ. *a*, intervertebral disc; *b*, body of vertebra; *c*, buttress-like processes of bone growing from one vertebra to another.

FIG. 13.—Mesial section of bodies of two dorsal vertebræ, completely fused together by growth of bone across the intervertebral disc.

Complete Fusion of two Vertebræ from the Growth of the Bone of the Body of the one into that of the other through the Intervertebral Disc.

SPECIMEN 14 (No. 1903). *Two dorsal vertebræ (bodies only).*—The bodies of these two vertebræ, which are from the lower dorsal region, are slightly approximated to one another, and united at their front and sides by thin marginal plates of bone extending from the articular margin of one vertebra to that of the other. In mesial section it is further seen that the two bodies are wholly fused with one another, the cancellous tissue of the one being continuous without any interruption with that of the other, the bone of each body having grown into and replaced the intervertebral disc (see Fig 13).

Ossification of Ligamenta Subflava, of other Ligaments, and union of Ribs with the Bodies of the Vertebræ.

SPECIMEN 15. *Portion of spine from an elderly person; eighth, ninth, tenth, eleventh, and twelfth dorsal and first lumbar vertebræ with eighth, ninth, tenth, and eleventh pairs of ribs attached.*—The laminæ of all the vertebræ are firmly united by dense and thick spiculated plates of bone extending from the upper to the lower borders of the adjacent laminæ (see Fig. 14). In this manner

all the vertebræ are rigidly held together, the bodies as in the natural condition being separated from one another by regular intervertebral-disc intervals. The bodies of the eighth, ninth, and tenth dorsal vertebræ are, however, united by marginal plates of bone. All the articular processes are firmly united. A section of one shows that the joint cavity has quite disappeared and that its place has been taken by somewhat dense cancellous bone tissue. The spines of the tenth, eleventh, and twelfth dorsal and first lumbar vertebræ are united near their free ends by bridges of bone, extending from one to the other in the position of the interspinous ligaments (see Fig. 14). The eighth, tenth, and eleventh pairs

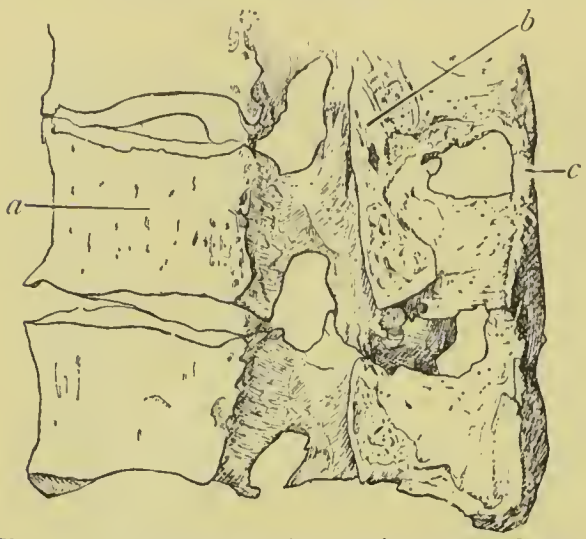

Fig. 14.—Antero-posterior section of last dorsal and first lumbar vertebræ just to one side of the middle line. *a*, body of vertebra; *b*, ossified ligamentum subflavum; *c*, ossified interspinous ligaments.

Fig. 15.—Horizontal section through a portion of the eighth dorsal vertebra and the vertebral end of the rib. *a*, body of vertebra; *b*, transverse process; *c*, neck of rib.

of ribs are firmly united to the bodies of their respective vertebræ, the eighth and tenth pair being also united to the transverse processes with which they articulate. It would seem that the heads of the ribs are in part joined to the bodies of the vertebræ by plates of bone forming in the situation of the anterior costo-vertebral ligaments; especially is this the case in the union of the tenth pair. A horizontal section through the head of the rib and the costo-transverse joint of the right eighth rib shows (see Fig. 15) that the costo-transverse joint is wholly obliterated; the tubercle and transverse process are fused together by a rather dense cancellous bone; whereas the costo-vertebral joint is only in part obliterated, there being still a central oval cavity; at the periphery of the joint for the extent of about one-twelfth of an inch the two bones are united by cancellous bone.

Remarks.—From the description of the preceding specimens it is clear that the vertebræ may become fixed to one another in various ways. A group of vertebræ may become fused to one another in their bodies—(1) by the formation of distinct bridges of bone which span over the intervertebral discs; (2) by the growth of marginal plates of bone from the edges of the bodies of adjacent vertebræ; (3) by the formation of a thick plate of bone extending over the bodies of several vertebræ in front in the position of the anterior common ligament or on one or both sides. These bridges and plates are usually composed of dense ivory-like bone, and they are, as a rule,

found in the front or on the sides, very rarely at the back of the bodies of the vertebræ.[1] The bodies of the vertebræ may also become fused to one another by ossification proceeding from the adjacent surfaces of the bodies through the intervertebral discs. There may also take place in the cervical, dorsal, or lumbar part of the column a process similar to that which occurs between the different bodies constituting the sacrum. It has also been shown that when the bodies are fixed either by marginal growths or otherwise, the intervertebral discs themselves may become separately and independently converted into bone, the piece of bone being limited above and below by thin dense laminæ just as are the vertebral bodies themselves. Other instances of this will be described further on. Just as the bodies of the vertebræ become fixed so may the neural arches, and occasionally fixation of the spine is due solely to ossification of adjacent margins of the laminæ of the vertebræ. The laminæ are, under natural conditions, held firmly together by means of yellow, elastic connective tissue, the *ligamentum subflavum*, which does, under certain as yet unknown circumstances, become converted into bone. Thus the laminæ may become joined to one another by bone and make a small or a great part of the column quite rigid and fixed. When this occurs it is usual to find that the joints between the articular processes are entirely obliterated, and that the adjacent articular processes become fused with one another; and not unfrequently it happens that the free ends of the spinous processes are rigidly held together by means of strips of bone, extending from the tip of one spine to another, in the position of the interspinous ligaments.

We may, therefore, find that in elderly men the vertebræ become fixed (1) by growth of bone on the exterior of the bodies of the vertebræ; (2) by the growth of bone from one body into another, across or through the intervening vertebral disc; (3) by ossification of the ligamenta subflava and interspinous ligaments and the fusion of the articular processes.

Neither in these cases of fixation of the vertebræ under morbid conditions, nor in those instances of natural fusion, as in the porpoises, do the pedicles show any tendency to become united by bone.

(*b*) *Ankylosis by Bone after Injury.*

I now purpose to describe four specimens which illustrate the changes that are liable to occur after injuries to the vertebræ, when such injuries are not grave enough to cause death immediately or soon after.

Specimen 16 (No. 1893). *Injury to atlas vertebra; occipital bone and the atlas vertebra.*—The atlas is sharply bent on its right side at the junction of

[1] Virchow in his *Archives* says that he found in some ancient specimens of vertebræ such processes had formed on the dorsal surface, and these must have pressed upon the spinal cord.

the posterior arch with the lateral mass; in consequence of this bend, the right half of the posterior arch is closely approximated to the adjacent part of the posterior border of the foramen magnum. The whole of the posterior arch, and all but the central portion of the anterior as well as the articular surfaces, are fused with the occipital bone; in addition the right transverse process of the atlas is fused with the lateral process of the occipital bone, the groove for the vertebral artery being destroyed and the foramen in the transverse process much reduced in size.

Many specimens more or less similar to the above are to be found in different pathological collections. Hitherto these have been regarded, especially by Schiffner ([18]), as due to some congenital abnormality; but the atlas is not only fused—usually in part—but it is distorted as if from injury at some time or other. I am, therefore, inclined to look upon a certain number of these specimens of ankylosis of the atlas to the occipital bone, especially where the vertebra shows signs of distortion as the result of injury, it may be, during adult life. Injuries to these parts are not of unfrequent occurrence, but what really happens is never known, owing to the fact that the injury is not grave enough to prove fatal, and that it is a part very difficult to investigate and that had better be left alone to effect its own repair.

Specimen 17 (No. 1894). *Partial dislocation of axis upon the atlas; occiput, atlas, and axis vertebræ.*—The occipital bone and the atlas are joined together by fusion of their articular surfaces, the margins of which are thickened and much outgrown. The axis is united to the atlas by fusion of their articular surfaces, but the former (axis) is somewhat displaced upon the latter, the second cervical vertebræ being rotated on a transverse axis so that the odontoid process is distanced from the anterior arch of the atlas by one-third of an inch. There is fusion between the left half of the anterior arch of the atlas and the adjacent portion of the body of the axis.

Specimen 18 (No. 1337B). *Fracture dislocation; cervical spine.*—The displacement in this specimen is of the usual type, and the injury is between the fifth and sixth cervical vertebræ. There is complete ankylosis of the bodies of the fifth and sixth, and of the sixth and seventh cervical vertebræ, also of the articular processes and laminæ of the same vertebræ. In mesial section the bodies of the fifth, sixth, and seventh vertebræ can be delineated, and the intervertebral discs can be made out, each one converted into cancellous bone. In part the ossified discs are fused and indistinguishable from the cancellous bone of the adjoining bodies, and in part distinct and well defined by a lower and an upper dense, limiting, thin plate of bone. The disc between the sixth and seventh vertebræ remains unossified in the middle. This portion of the spinal column was removed from a man who lived twelve years after the date of the accident when he fell from a height backwards and broke his neck.

Specimen 19 (No. 1341). *Fracture dislocation at junction of twelfth dorsal with first lumbar vertebræ.*—The displacement is slight and of the usual kind, namely, the upper fragment forwards and downwards upon the lower, the upper and anterior part of the body of the lower vertebra (first lumbar) being broken off. The bodies of the twelfth dorsal and first lumbar vertebræ are united anteriorly and at the sides by a thin marginal plate of bone, which has grown from the articular margins of adjacent bodies, and behind by a similar plate of bone which is continuous with the ossified hinder part of the intervertebral disc, the greater part of the disc, however, being in its natural fibro-cartilaginous

state. The articular processes are fused together by cancellous bone, but the laminæ are widely separated, and there is no attempt at union between them. Between the anterior parts of the body of the first and second lumbar vertebræ, which parts are unduly approximated, there are also marginal growths; they are, however, un-united. This specimen was removed from a man who lived fourteen years after the accident.

Remarks.—The changes described in the above specimens are practically identical with those observed in the spines of elderly people, and the ankylosis is liable to take place, not only between the damaged vertebræ, but also between neighbouring ones.

(*c*) *Ankylosis in cases of Tubercular Disease.*

In these cases there is not only a fusion of all the bodies implicated in the disease and forming the angular curvature, but there is also fusion of the neural arches and of many adjacent ribs to one another and to the diseased vertebræ. In addition, there is in the lumbar region a very remarkable development of bridges of bone, which expand over and fix the diseased vertebræ; and in this region, it will be remembered, it is usual to find the disease quite limited, consisting of a necrosed plate of bone in a part of the body adjacent to the intervertebral disc.

Specimen 20 (No. 1573). *Spinal column after extensive tubercular disease of the bodies of the four lower dorsal vertebræ.*—The bodies of the ninth, tenth, eleventh, and twelfth dorsal vertebræ are fused together into a wedge-shaped mass of cancellous tissue, in which there are no traces whatever of division into separate vertebræ, the intervertebral discs having completely disappeared. The laminæ and articular processes of these four vertebræ are in like manner fused with one another. In addition, there are marginal growths at the angle of junction of the body of the eighth, with the mass formed by the fused four lower dorsal vertebræ.

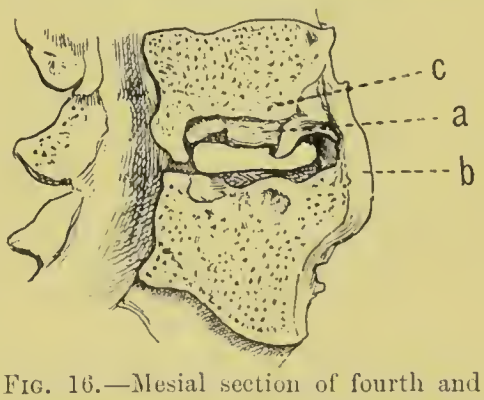

Fig. 16.—Mesial section of fourth and fifth lumbar vertebræ. *a*, cavity in body of vertebra which contains a scale of necrosed bone; *b*, thick bridge of bone joining and fixing the two vertebræ; *c*, body of fourth lumbar vertebra.

Specimen 21 (No. 1573). *Localised tubercular disease with necrosis of the lower part of the body of the fourth lumbar vertebra.*—The bodies of the fourth and fifth lumbar vertebræ, which retain their natural distance from one another, are fixed together by means of a strong narrow bridge of bone situated in front and spanning over the intervertebral space. From the upper part of the body of the fourth lumbar vertebra, tooth-like processes of bone are seen growing upwards over, or in front of, the intervertebral space, to meet similar but smaller growths from the lower margin of the third vertebra which is not affected with disease. In this manner the two vertebræ, fourth and fifth, became fixed, the formation of this bridge of bone being prompted by the disease of the lower part of the body of the former. In this part of the column in the adult, owing, perhaps, to the natural curve forwards, angular curvature does

not usually arise, but in its stead fixation of the affected part takes place by means of the formation of such strong bridges of bone spanning from one vertebra to another (see Fig. 16).

(*d*) *Ankylosis in Lateral Curvature.*

It is only in extreme forms of this disease that any ankylosis occurs. Not only may the neural arches, articular processes, and ribs be ossified to one another, but the bodies may be united by marginal growths, the intervertebral disc ossified or the bodies so completely fused together by growth from one to another through the disc, that it is difficult and even impossible to distinguish one body from another.

Fig. 17.—Section through four lower dorsal vertebræ in lateral curvature. *a*, body of ninth; *b*, ossified intervertebral dise between ninth and tenth; *c*, fused bodies of tenth, eleventh, and twelfth.

Specimen 22 (No. 1491A). *Extreme lateral curvature of the four lower dorsal vertebræ.*—The bodies of the last three dorsal vertebræ are completely fused, with the exception of the hinder and lateral parts of the eleventh and twelfth, into one single piece of cancellous bone, upon which rests the fairly defined body of the ninth vertebra. The body of this vertebra—the ninth—is fused with that of the tenth in front, the cancellous tissue of the one being continuous with that of the other. Behind, the body of the ninth is separated for nearly half an inch from that of the tenth, and the interval is occupied by the thickened intervertebral disc which is converted into cancellous bone. This cancellous bone, occupying the place of the fibro-cartilaginous disc, is defined above and below by a thin dense plate of bone, except in front, where it is thinner and in part fused with the cancellous tissue of the adjoining bodies (see Fig. 17). The laminæ and the articular processes are well joined together by bone.

Specimen 23 (No. 1500). *Lateral curvature of spine to the right in the lower dorsal region.*—The vertebræ from the fourth to the twelfth are involved in the curve which is very marked. On the concave side of the curve (left) the bodies of these vertebræ are connected either directly by growth of bone from one opposed body to another or by marginal growths.

On the concave sides of both upper and lower compensating curves, similar changes have taken place, especially in the upper curve which is sharp and short. The laminæ and articular processes of the eighth to the twelfth dorsal vertebræ are joined together by bone on both sides; the transverse processes of the lower six dorsal vertebræ on the concave side are fused to one another and are almost indistinguishable. The spines of the eleventh and twelfth dorsal vertebræ are joined together by a considerable nodulated mass or lump of bone on their left sides. The seven lower ribs on the concave (left) side are fused with their respective bodies, and the transverse processes of the vertebræ are

in part fused together. Similar but less extensive changes have taken place between the vertebræ and the ribs on the concave side of the upper sharp and short compensatory curve, the ribs being, however, more extensively fused.

In lateral curvature of the spinal column the degree of ankylosis of the bodies of the vertebræ to one another varies very much, it being rarely so complete as in the last but one specimen described. The neural arches and the adjacent portions of the approximated ribs in the dorsal region are much more liable to fuse with one another than are the bodies.

There remains to be considered in the axial skeleton the sternum, ribs, sacro-iliac, and inter-pubic joints. No attempt will be made to follow, in regard to these, the classification so far adopted, but the general plan will, so far as possible, be adhered to.

The Sternum.

The several pieces of the sternum are usually ankylosed to one another in persons of middle age. Though the sternum is commonly the seat of congenital malformations, yet, so far as I can determine, its segments are only with extreme rarity ankylosed to one another at birth. Further, the sternal joints are remarkably free from disease, and but rarely dislocated, so that it would be rare to find ankylosis from either of these two conditions. The specimens that are here described show only the common form of ankylosis, namely, that which comes on in adult life.

Specimen 24. *Fusion of manubrium and body of sternum.*—The manubrium is firmly united to the body. On the exterior of the junction there is a slight smooth ridge of dense ivory-like bone. On mesial section there is to be seen just a trace of the joint cavity, the indication being a thin line of dense bone. Otherwise the cancellous bone of the one part is continuous with that of the other. The xiphi-sternum is not united to the body.

It may be remarked that this process of ankylosis is identical with that seen between the bodies of the sacral vertebræ, union taking place at the periphery first and subsequently extending into the interior of the joint. It may also be noticed in passing that the angle of Ludwig is in reality due to the formation of bone on the anterior surface of this joint, and not to an angle between the manubrium and the body of the sternum.

Specimen 25. *Fusion of xiphoid cartilage which has become converted into bone with the body of the sternum.*—The xiphoid cartilage, which is entirely converted into bone, is united to the body of the sternum, and on the exterior of the joint there is a thin layer of dense bone as in the preceding specimen. The manubrium is in this specimen free, there being no evidence of any attempt at ankylosis between the pre- and meso-sternal joint.

Ossification and Ankylosis of Costal Cartilages to the Sternum and to the Vertebral Ribs.

Ossification of the costal cartilage has usually been regarded as the result of age,—a senile process,—but it is now well known that ossification of these cartilages may be absent in elderly people. It is, however, almost invariably present in adults of different ages who have suffered from cardiac disease complicated with pulmonary troubles, and from chronic chest complaints of various kinds. Sir George Humphry ([20]) refers, in his work on the Human Skeleton, to the dissection of a centenarian by Dr. Harvey, in whom the costal cartilages were soft; and to a skeleton of a person, æt. 100, in the Berlin Museum, in which the cartilages are likewise soft and supple; and he says, "In almost all the old persons in whom I have had the opportunity of making a post-mortem examination, I have observed the cartilages of the ribs to be discoloured and yellowish, but soft, so as to yield easily to the knife, and render the saw unnecessary; whereas they are commonly ossified and requiring to be sawn through in adults who have been addicted to drinking and have become unhealthy. I am on the whole, therefore, disposed to regard the ossification of the costal cartilage as a sign of disease rather than of age."

The costal cartilages have, therefore, a tendency to ossify, and that is especially the case when the person suffers from chronic chest complaints, and probably after being much addicted to alcohol. The process of ossification is probably much the same, whatever be the cause, and it is to this that I more particularly wish to refer. The costal cartilages, or sternal ribs, as they are called in comparative anatomy, do in a great many animals undergo ossification as a part of their development. For example, in the horse, the costal cartilages are throughout their extent ossified, and they articulate by means of synovial joints with the rib at the one end and with the sternum at the other. The ossification begins in the interior of the cartilage, and new bone gradually replaces the cartilage from within outwards, that is to say, it is endosteally formed. In the monotremes, on the contrary, in which the costal cartilages early ossify, the ossification results, according to Parker, from the formation of bone on the exterior of the cartilage, and by extension of bone-formation from without inwards; that is to say, it is formed ectosteally. In each, the same result, namely, ossification of the sternal ribs, ultimately takes place.

It will presently be shown that these two forms of ossification in the costal cartilages, the endosteal and the ectosteal, take place in man under the conditions above referred to. But the ectosteal variety is far more pronounced and more important than the endosteal, which may indeed be characterised as insignificant.

The ectosteal formation of bone in the costal cartilages is usually most pronounced in the first, and less in the succeeding cartilages;

and so far as my observations go it is far more frequent than the endosteal.

1. *Ectosteal Bone-Formation in the Costal Cartilages.*

Specimen 26 (No. 1533c). *Manubrium sterni and right first rib.*—The costal cartilage and adjacent parts of the sternum and of the first rib are covered by a thick layer of smooth, uneven, and dense bone. This new bone is in part directly continuous with that on the first rib and with that on the sternum, but in part it is separated from each by a sinuous narrow fissure. A longitudinal section through sternum, costal cartilage, and distal end of rib shows a thick layer (one-sixth of an inch) of bone, that is in places dense, and in others cancellous, surrounding the costal cartilage, which is of normal size and which shows few small centres of ossification in its anterior. In short, the first costal cartilage is surrounded by a sheath of bone one-sixth of an inch thick, which is united at each end with similarly formed bone on the adjacent parts of the first rib and of the sternum (see Fig. 18).

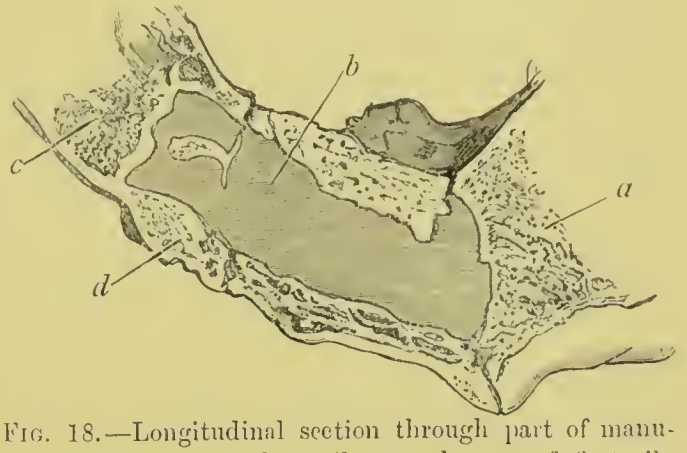

Fig. 18.—Longitudinal section through part of manubrium sterni, costal cartilage and part of first rib. *a*, manubrium sterni; *b*, costal cartilage; *c*, first rib: *d*, sheath of new bone formed on outer surface of first costal cartilage.

Specimen 27. *Sternum, costal cartilages, and adjacent parts of ribs from a man, æt. 73 years, who had suffered much from chronic bronchitis.*—All the costal cartilages are to a more or less degree covered on their exterior with a layer of dense bone, forming an imperfect sheath to the cartilage which is almost normal. These partial sheaths of all the cartilages are continuous either with the outer layer of the end of the rib or with that of the sternum; and the sheath is, as a rule, more complete at each end than in the middle, where it may be quite absent or very imperfect. The condition shown by the above specimen is the one commonly met with.

If a piece of costal cartilage which shows this ectosteal formation of bone be examined under the microscope, it will be observed that the bone found at the periphery and under the original perichondrium, differs in many respects from ordinary bone. It consists of trabeculæ of bone faintly laminated, and with but few stunted bone corpuscles. These trabeculæ are separated by small or large spaces filled with cells —small, round, and spindle-shaped—or with fibrous tissue containing many large fat cells. In some places the trabeculæ are very thick and the intervening spaces small, rendering these parts very dense. The bone cells in the trabeculæ are, in the majority of instances, very small and contracted, having no branches extending into fine canaliculi as in normal bone. The lamellæ, as has been said above, are not very distinct, and they are not arranged in systems or, indeed, in any sys-

tematic manner. Here and there the manner in which the formation of the bone trabeculæ takes place may be observed; for the matrix of the fibrous tissue that precedes the formation of bone is in places converted into a very granular opaque substance, which in its turn is converted into lamellæ presumably of uniform structure.

Accordingly, the bone here formed consists of precisely similar elements to those in a natural bone, but the arrangement is different from that seen in a normal bone.

2. *Endosteal Bone-Formation.*

The formation of bone in the interior of the costal cartilages is the condition usually described, but this variety though normal in many animals is really insignificant in man, although it is of frequent occurrence in association with the ectosteal variety. There is usually formed a more or less continuous rod, running along a part of or, indeed, the entire extent of the cartilage. In these specimens the bone in the interior is, if anything, less characteristic than that on the exterior of true bone; the trabeculæ are thick and of irregular size, the lamellæ composing them are very indistinct, and the corpuscles are stunted and without delicate processes, the canaliculi for which are absent. Accordingly, the endosteal is similar in its structure to the ectosteal bone of the costal cartilages.

Besides this formation of bone in the interior of the costal cartilages there occurs, in places here and there, calcification, which is preceded by fatty degeneration of the cartilage cells and by fibrillation of the cartilage matrix.

Ankylosis of the Sacro-Iliac Joints.

1. *Congenital or Pre-Natal.*

Congenital ankylosis of the sacro-iliac synchondrosis, with defective growth of the lateral mass of the sacrum, was first described by Naegélé. The want of development which may or may not be due to the ankylosis of the sacro-iliac synchondrosis determines the formation of the "obliquely contracted" or Naegélé pelvis. Naegélé ([21]) in his memoir shows that this condition is rare in women and still rarer in men; and further, he points out that though it is usually associated with ankylosis of the sacrum to the ilium, yet the deformity may exist when there is no such ankylosis, but merely defective development of the lateral mass of the sacrum. In describing the causes of this remarkable deformity, he ends by saying that he thinks it is due to an error in development and not to any general or local disease. Since Naegélé's work, cases have been recorded by Robert ([22]) in which both sacro-iliac synchondroses were ankylosed and both lateral masses of the sacrum were defective. In such instances the pelvis reverts to the

condition commonly seen in mammals, that is, it is flattened from side to side, and consequently is deeper dorso-ventrally than from side to side.

2. *Post-Natal.*

Ankylosis of the sacro-iliac joint is commonly met with in elderly people, but rarely in young persons, in whom it follows upon some destructive disease, such as tuberculosis of the joint. We shall, therefore, consider this under the two headings—(1) in elderly persons; and (2) after suppurative disease of the joint.

(1) *In elderly people.*—Ankylosis of the sacro-iliac joint in elderly people is so common that specimens of it are abundant. In these the fixation of one or both joints takes place—(1) from the formation of a thick dense bridge of bone on the front of the joint; (2) from the growth of the ilium into the lateral mass of the sacrum across the joint cavity; and (3) by a combination of both. It is no doubt rare to find such ankylosis due only to growth of bone across the joint, as Rokitansky observes, but commonly there is more or less complete fusion when the joint is firmly bridged over in front as the few specimens herein described show.

Specimen 28. *Ankylosis of both sacro-iliac joints in a male pelvis.*—The line of the sacro-iliac joint on each side is discernible only by a ridge of dense bone, the iliac bones being firmly united or fused to the sacrum. In a section to expose the joint cavity in its entire length on the left side, the upper half of the joint can be made out, for in its place there is a thin line of dense bone; below, however, all traces of the cavity of the joint have disappeared, the cancellous bone of the wing of the sacrum being directly continuous with that of the iliac bone without any sign of interruption. The fusion of the two bones on this side is complete. All the bodies of the sacrum are also united by bone. In addition, the lower half of the small sciatic ligament is converted into a thin process of bone, and there are numerous small bony outgrowths from the margins of the iliac bones.

Specimen 29 (No. 1903). *Ankylosis of left sacro-iliac joints.*—Left os innominatum, evidently from a man, is united to the sacrum by a thick bridge of dense, almost ivory-like bone, at least half an inch in thickness and $1\frac{1}{2}$ in. in length, extending over the upper and fore-part of the sacro-iliac joint. The lower part of the joint is natural, the two bones being separated from one another by the usual ($\frac{1}{8}$ in.) interval. The first two sacral vertebræ, the only remaining ones, are united by bone.

3. *Ankylosis after Suppurative Disease.*

This joint, like others of a similar nature, is not exempt from the invasion of the tubercle bacillus. Hence, we find that it is not uncommonly the seat of tubercular disease which, when it has existed some time, is very likely to end in suppuration. Although such cases are very troublesome and unsatisfactory to treat, yet a few of them recover, and with recovery the joint cavity is obliterated, and the sacrum and ilium united, as is shown in the following specimen :—

Specimen 30 (No. 1810z). *Male pelvis.*—The left sacro-iliac joint is ankylosed by bone, the sacrum and the left ilium being fused with one another. In the upper part of the joint there are several large pits, and there is one hole through the ilium, all of which indicate that there must have been chronic destructive disease of the joint. In this specimen there is no bridging over of the articular surfaces as in the preceding examples, the articular surfaces being directly united by bone.

Doubtless suppurative diseases, other than those set up by the tubercle bacillus, may and do occur in this joint, and when they end in recovery, ankylosis of this kind probably results; and it may be that accidents to this joint in early life lead not only to bony ankylosis, but also to defective development of the corresponding lateral wing of the sacrum and in some measure to stunted growth of the ilium.

The Symphysis Pubis.

Though the symphysis pubis is so frequently ossified in the lower animals, either throughout or in part of its extent, in man such an ossification even in elderly persons is very uncommon; and, indeed, this is rare as a sequel to disease which is here very seldom met with except in a grave and fatal (septic) form.

Ankylosis by bone of the pubic bones does not occur in any of the various deformities of the pelvis in women nor in man; and, singularly enough, when both sacro-iliac joints are rigidly fixed by fusion of the bones and when many vertebræ are in like manner fixed to one another in elderly persons, men especially, the symphysis pubis is the only joint that shows no trace of any change that would lead to ankylosis.

Still, complete fusion of the ends of the pubic bones across the symphysis does take place. Wagner ([23]) depicts and gives an account of such a case, but whether this instance followed upon suppurative or non-suppurative disease it is impossible to tell. It is worthy of note, however, that in skeletons affected with universal ankylosis or ossifying arthritis, a condition which will be described in a succeeding paper, ossification across the symphysis pubis does take place.

Just as bony ankylosis of the joint itself is rare, so is fixation of the joint by the formation of bridges of bone from one side to the other. An example of this I have recently obtained through the kindness of Professor Macalister, and the description of it is as follows:—

Specimen 31. *Pelvis from an old man.*—The symphysis pubis is bridged over above and behind by a thick and somewhat dense lamina of bone, which is continuous with a similar plate extending downwards behind the left pubic bone to the pelvis. There is no growth of bone across the joint cavity. Both sacro-iliac joints are similarly bridged over above and in front. In this manner the three bones constituting the pelvis are united to one another at the sacro-iliac joints and at the symphysis pubis.

IN THE APPENDICULAR SKELETON.

The appendicular skeleton differs in some important respects from the axial, and before we begin to consider the ankyloses, natural and morbid, which may arise in its several joints, a brief review of the peculiarities of the limbs may first be given.

Each of the four limbs of vertebrates is composed of a series of segments, one beyond the other, just as the axial skeleton is composed of a series of vertebræ, one behind the other. In a limb, however, there are not only segments jointed end to end so as to allow of a greater or less range of movement, and upon which their usefulness in great measure depends, but in the individual segments as we proceed from the shoulder girdle towards the hand the number of bones, roughly speaking, in each succeeding segment increases. For example, in the human arm the first segment contains only one bone, the humerus; the second, two—radius and ulna; the third, three—scaphoid, semilunar, and cuneiform; the fourth, four—the trapezium, trapezoid, os magnum, and cuneiform; the fifth, the five metacarpals; the sixth and seventh, five phalanges each; and the eighth, the four terminal phalanges of the fingers. Accordingly, as we proceed from the proximal to the distal extremity of a limb the segments divide into so many separate bones which may be clothed by one fold of skin as in the forearm, or by separate folds as in the digits. In the limbs, therefore, we have to deal not only with ankylosis of the joints between segment and segment, but also between the separate divisions of a segment whether connected by joints or otherwise.

In the axial skeleton it has been shown that bony ankylosis of segment to segment takes place in different animals under natural conditions; in the appendicular skeleton, however, fusion of segment to segment end to end is very uncommon under natural conditions though frequent in disease. But though fusion of segment to segment in a limb under natural conditions is rare, yet fusion of the separate divisions in a segment is comparatively common, and it is by means of the lateral approximation and ultimate fusion of separate bone divisions in a segment that we obtain many of the varieties in the limbs of different classes of animals.

Further, pre-natal or congenital ankylosis, usually shows itself by lateral fusion of two or more divisions in a segment, and but rarely by fusion of two or more segments end to end. In disease, on the contrary, fusion of segment to segment is what generally happens, though, as will be pointed out further on, lateral junction of bones does now and again take place.

Ankylosis in the limbs will be considered under the same classification as that of the axial skeleton, the subdivisions only being modified.

I. NATURAL.

1. In Vertebrates.
2. In Man.

II. MORBID.

1. Pre-Natal or Congenital.
   (*a*) Fusion of segment to segment.
   (*b*) Fusion by lateral approximation of the separate elements in a segment.
2. Post-Natal.
   (*a*) After septic arthritis, whether the result of direct or indirect infection.
   (*b*) After tubercular arthritis—(1) with and (2) without suppuration.
   (*c*) In a joint adjacent to another joint severely inflamed, or at the end of a long bone in a similar state.
   (*d*) After injuries.
   (*e*) In disease or injury of the nervous system.
   (*f*) In ossifying arthritis.
   (*g*) Under uncommon conditions.

I. Natural Ankylosis by Bone.

1. In Vertebrates.

Owing to the variations in the skeletal parts of the limbs of different vertebrates there is abundant material for the illustration of the fusion of two or more divisions in a segment; and this is especially the case in those animals in which the separate bones in a segment become approximated and fused to form one solid piece of bone. A striking example of this is to be found in the fore-limb of the *Hippopotamus amphibius*. In this animal the radius and ulna are of nearly equal size, and they are fused to one another at both extremities—at the radio-ulnar articulations—and along the lower or distal five-sixths of the shafts, the radius and ulna being thus united so as to serve the purpose of a single bone. In the common pig both radio-ulnar joints become ankylosed, but the shafts of the bones remain free and distinct from one another. Between these two conditions every grade of fusion may be met with.

The lateral approximation and fusion of metacarpal and metatarsal bones, but not of the phalanges of the fingers, is best illustrated in the Artiodactylæ, a good example of which is the common ox, *Bos taurus*, in which the metacarpals and metatarsals of the third and fourth digits of the manus and pes respectively are united by their lateral borders. Similar fusion is seen in the foot of the bird and in the foot of the jerboa, a rodent we have already mentioned as having several cervical vertebræ fused to one another.

2. In Man.

In man, however, this fusion of two or more divisions of a segment does not occur except under abnormal conditions which arise both before

and after birth; but there is a solitary instance of the fusion of segment to segment, and that is in the little toe. Although the little toe at birth and in the earlier years of adult life contains three separate phalanges and interphalangeal synovial joints, yet in a large proportion of persons at and beyond the middle period of life, the second and terminal phalanges are so fused together as to constitute one single piece of bone in which there is, as a rule, no trace of the joint that formerly separated them. Such a specimen is illustrated in Fig. 19.

Fig. 19.—Mesial and longitudinal section through the second and terminal phalanges of the little toe of a middle-aged person (×2).

Whether this is the result of the mechanical worry the little toe is so commonly subjected to by the wearing of tight and ill-fitting boots, or whether it is an indication of a tendency to the natural diminution in the number of phalanges prior to ultimate disappearance of this somewhat useless digit, is more than I would at present venture to suggest.

Remarks.—We accordingly find that both in vertebrates and in man ankylosis under natural conditions is not nearly so common in the appendicular as in the axial skeleton. This agrees with what we should expect, for many of the bones of the axial skeleton may become rigidly fixed without greatly interfering with its usefulness, and, indeed, perhaps render it more useful; whereas, in the appendicular skeleton, fusion of one segment to another would greatly interfere with the usefulness of a limb. Even in whales, tortoises, seals, and walruses, fusion of segment to segment in the limbs does not take place, and the several junctions, if not formed by synovial joints, consist of fibrous tissue so as to allow of some degree of pliability.

Although the fusion of segment to segment does but rarely occur under natural conditions in the limbs, yet fusion of two or more bones in a segment by lateral approximation takes place commonly enough in vertebrates. In man, however, as will be immediately shown, fusion of the separate bones in a segment is of not infrequent occurrence under abnormal or diseased conditions before and after birth.

II. Morbid Bony Ankylosis.

1. Pre-Natal or Congenital.

Congenital bony ankylosis is, like the natural variety in the appendicular skeleton, much more common between the different bones of a segment than between separate segments, and lateral fusion is more frequently met with between the phalanges of the fingers and toes than elsewhere. Both fingers and toes, it is well known, are liable to fusion to a greater or less degree along their lateral borders constituting the condition known as syndactylism;

this fusion may involve one or more of the phalanges. Usually it is the more distal bones and not the metaearpals or metatarsals, as in ankylosis under natural conditions, that beeome thus united; and the degree of fusion may be sueh as to show merely the line of junetion, or the separate bones may be completely welded together. Sueh a fusion of the separate divisions in a segment of the limb is well illustrated by a case of syndactylism reported by Otto, and quoted and figured by Annandale ([24]), in which two fingers were euelosed by one continuous fold of skin, and in which the seeond and the terminal phalanges were completely fused by lateral approximation, the first phalanges being free. This is in nature precisely what happeus in the case of the fusion of the third and fourth metacarpal bone, for example, in a pig.[1]

Although the first form of congenital bony ankylosis is eommon enough, yet the second, namely, the fusion of segment to segment, is eomparatively rare. When this oeeurs, it must be very diffieult without demonstrable proof to be sure whether in ease a finger is represented by two phalanges only, the eondition is due to pre-natal, or congenital fusion of two phalanges, or to want of differentiation of the three separate segments during the laying down of the skeletal parts. Without attempting to deeide to whieh of these two modes it belongs, I will here deseribe a speeimen whieh shows eongenital ankylosis of the phalanges of the toes:—

Specimen 32 (No. 2088). *The right foot of a fœtus probably at full term.* —The toes were covered in a sheath of skin, with slight indentations between the ends of the digits. In the big toe the terminal phalanx is large and well ossified, but the first phalanx is absent. In each of the remaining toes the skeletal parts are represented by a single piece of hyaline cartilage, showing no evidence of the formation of joints; in the proximal portion there is a large nucleus of cancellous bone, and in the distal part a second small one (see Fig 20). The joints between the digits and the metacarpal bones are natural. In the right hand of the same fœtus the digits were represented by two nuclei of ossification without intervening joints, and the terminal phalanges of the second, third and fourth fingers were laterally expanded and joined to one another.

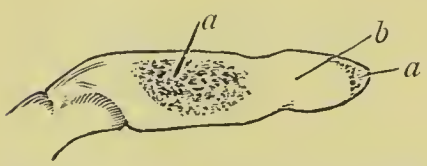

Fig. 20. — Longitudinal section through one toe. *a*, bony nuelei; *b*, hyaline eartilage (× 2).

2. Post-Natal Bony Ankylosis.

(*a*) *Bony Ankylosis in Septic Arthritis, whether the result of Direct or Indirect Infection.*

In examples of septie arthritis different degrees of severity of the inflammatory process are seen. For instance, in those eases of direet infeetion, either from penetration of the joint eavity by an infected

[1] There is in the Museum of St. George's Hospital a very good illustration of congenital fusion by lateral approximation of tibia and fibula for about one inch in extent at a level about two inches above the inferior tibio-fibular articulation (Ser. iii. 33D).

instrument or by opening of the joint in the treatment of disease, it is usual to find that the resulting inflammation is very severe, and that suppuration of a determined nature supervenes, causing destruction partial or complete of the soft structures of the joint and sometimes of the articular ends of the bones; whereas in cases of indirect infection, as occurs in gonorrhœal rheumatism, in puerperal fever, in pyæmia and after specific fevers, especially typhoid, the resulting inflammation is generally not so severe, the fluid in the joint only at times becoming true pus, usually being only turbid from the presence of a comparatively small number of exuded white blood corpuscles; consequently, in these cases the destruction of the joint structures is not so great as in those due to direct infection, and therefore the tendency to osseous ankylosis is proportionately less. In septic arthritis of any kind, after indirect as well as direct infection, the articular ends are usually not much altered, there being but little if any destruction of bone tissue.

The articular cartilage and the inter-articular ligaments, however, disappear, and the articular ends of the bones being covered with granulation tissue become united wherever they are in contact by the growth of that tissue on opposed surfaces; this may subsequently become fibrous connective tissue or true bone. If the uniting medium becomes converted into bone, then the two articular ends become completely united, the cancellous tissue of one bone becoming directly continuous with that of the other. The knee joint illustrates this perhaps better than any other, simply because it is largest, and the one commonly affected.

The following specimen well illustrates the results in this variety of bony ankylosis:—

Specimen 33 (No. 1885a). *Ankylosis of knee joint.*—Femur, patella, tibia, and fibula of a young adult in whom the lower epiphysis of the femur and the upper one of the tibia are not fully fused with their respective shafts. The limb is slightly bent forwards. The femur, tibia, and fibula are natural, except that they are covered along almost their entire extent with numerous short spicules of bone. The patella, which is in the position it occupies in extension of the knee, is firmly ankylosed at its lower part, its only point of contact with the femur. The femur and tibia are also firmly united by bone. The line of the former joint can be easily traced on the exterior, where there is on each much coarsely spiculated new bone; and the upper portion of articular surfaces of the condyles of the femur, which would naturally not be in contact with any other bone, are covered by a thin irregular layer of new bone. In a transverse section through the femur and tibia the cancellous bone of the femur is so blended with that of the tibia, except for a short space near the middle, that there is no trace whatsoever of the line of the old joint cavity. There is no evidence of destruction of the articular ends of the bones or of any other disease.

(*b*) *After Tuberculosis of Joints.*

Tubercular disease of joints is met with in many forms, but for our purpose these may all be included under tubercular arthritis *with* and *without* suppuration.

Tubercular disease without suppuration.—Bony ankylosis, without suppuration in tubercular disease of joints has been recently described by Howard Marsh ([16]) in the paper already referred to; and the case he gives, he tells me, is only an instance of what he has met with in his practice on several occasions. It is true that in this case there is no absolute and demonstrable evidence that the disease of the joint was of a tubercular nature, and therefore we cannot speak of it as an indisputable example of osseous ankylosis following upon tubercular arthritis without suppuration.

The account is as follows:—

"The elbow joint of a girl aged 14, had gradually, without symptoms, become fixed at an angle of about 130°. To unfree this position Dr. W. Roughton, of New Barnet, performed excision." In a section of the specimen, which is figured, the humerus and ulna are completely fused together, there being no trace of separation between them. There is no evidence of disease.

Tubercular disease with suppuration.—On the contrary, examples of osseous ankylosis following upon tubercular disease with suppuration, are common enough, and it is not necessary to give more than a few instances, one of which I knew, from personal observation, to have arisen from chronic tubercular disease which was associated with suppuration and discharging sinuses.

Specimen 34 (No. 1810m). *Left elbow ankylosed by bone.*—The ulna is united to the humerus by bone at an angle a little greater than a right angle. There appears to have been no great destruction of the articular ends, but at the articular margins of each bone there has been considerable osteophytic growth, the line of junction being still detectable. The radius was united by fibrous connective tissue to the capitulum. In longitudinal section through the middle of the olecranon and the trochlear portion of the humerus there is no trace of the former joint cavity, the cancellous tissue of the trochlear portion being directly continuous with that of the olecranon; and there appears to have been but little if any real destruction of bone in the articular ends, as the line of union and outline of the trochlea and greater sigmoid fossa, can still be traced (see Fig. 21).

Fig. 21.—Longitudinal section through the trochlea and olecranon of an ankylosed left elbow joint (nat. size).

This was removed from a man aged 29 years, who died from phthisis, having suffered from tubercular disease in various parts of his body. There were the remains of several sinuses around his left

elbow joint which had been the seat of disease for a considerable time when he was a lad.

Several joints may become thus ankylosed, as is often seen in the carpus and in the tarsus.

The following specimen shows fusion of the tarsal bones:—

Specimen 35. *Bones of the tarsus of the left foot.*—The scaphoid, cuboid and three cuneiforms are osseously united, there being no trace of any of the joints between them. The hinder and upper parts of the middle and outer cuneiform and the adjacent part of the scaphoid have completely disappeared, and there is in the anterior and lower part of the internal cuneiform a large cavity. A section (vertical) through the scaphoid and internal cuneiform shows the fusion between these two bones to be complete, the cancelli of the one being directly continuous with those of the other. The anterior articular surfaces of the middle and outer cuneiform bones are rough and uneven, as if they had been joined to their respective metatarsals by fibrous tissue; the hinder articular surfaces of the scaphoid and those of the astragalus are natural. The astragalus and os calcis show no signs of disease.

(*c*) *Bony Ankylosis of a Joint adjacent to another Joint severely inflamed or at the end of a long bone in a similar state.*

When speaking of tubercular disease in the bodies of the vertebræ it was pointed out that after its subsidence the synovial joints between the articular processes, as well as the laminæ of the affected vertebræ, were commonly found ankylosed to one another by bone, though these joints it may be safely asserted, were never the seat of tubercular disease. Again, after injuries to the spine,—fracture dislocation, for example,—the articular processes in addition to the damaged bodies are usually found ankylosed. Doubtless some changes take place in these joints which lead ultimately to ankylosis; and these changes are, I venture to think, the result of the joints being situated in the immediate neighbourhood of the seat of disease. Similar results, though not nearly so frequent, are met with in the joints of the limbs, especially those of the tarsus; and the ankylosis may be either *fibrous*[1] or *osseous*. Further, severe inflammation of a long bone may be associated at one or other of its extremities with a variety of arthritis, which leads to osseous ankylosis, as will be presently shown.

The first two specimens I will refer to illustrate the occurrence of osseous ankylosis in a joint next to another the seat of *chronic* tubercular disease. The first of these was described by Mr. Howard Marsh, and shown to the Pathological Society of London in March 1896.

The foot was amputated for chronic tubercular disease of the ankle joint, and on investigation it was found that the astragalus and os calcis were so blended with one another that there was no line of

[1] In the Museum of the Royal College of Surgeons, Edinburgh, there is a specimen showing fibrous union between the os calcis and the astragalus, following upon tubercular disease of the ankle joint.

separation between them, and that the cancellous tissue of the one was directly continuous, without any signs of interruption, with that of the other; and there was no evidence of disease of the astragalo-calcaneal joints.

The second specimen, consisting of the left tibia, fibula, astragalus, and os calcis, is in the Pathological Museum of St. George's Hospital (Ser. iii. 32A). The ankle joint had evidently been the seat of destructive tubercular disease, the tibia and astragalus being in part united by bone and in part separated from one another by irregular cavities. The os calcis, which is natural in every respect, is intimately united to the astragalus, so that they practically form one bone. Owing to the eversion of the foot, which is rather strongly marked, the tip of the external malleolus had at first come in contact with, and later become joined to the external surface of the os calcis. There are no signs of disease in the joints between the astragalus and os calcis. These bones were removed by amputation from a woman, aged 38 years, who had had pain and swelling in the ankle for 6 years; during the last six months preceding the amputation, abscesses formed in and about the joint.

Ankylosis of a joint at the end of a long bone affected with acute necrosis.—The occurrence of bony ankylosis in a joint, say for example the ankle, when the tibia is the seat of active inflammatory disease, is hardly recognised, although the fact that certain changes are liable to occur in joints placed under such circumstances is familiar enough. From the specimens I am about to describe it will be seen that osseous ankylosis may and does occur at times. It is true that, as I have just said, arthritic changes of some kind arise, and often lead to stiffness when one of the bones is the seat of active inflammation; but it is very uncommon to find that any suppuration takes place in these joints. I am therefore inclined to regard the specimens to be immediately described as due not to suppurative arthritis but to a special form of arthritis, allied to that which takes place in the joints between the articular processes of diseased vertebral bodies, as in Pott's disease.

Specimen 37 (No. 1610). *Ankylosis of tibia, fibula, and astragalus.*—The tibia shows the results of extensive osteomyelitis with necrosis. The fibula is natural. The lower end of the tibia, the lower end of the fibula, and the astragalus are joined together by bone. The line of junction of the different bones can just be traced on the exterior but not in a mesial longitudinal section; the tibia and astragalus are quite fused together, there being no line or mark to indicate their junction. The epiphysial lines at the lower ends of the tibia and fibula have completely disappeared, though those at the upper ends are present. There appears to be no evidence of destruction of bone in the articular ends of the tibia and fibula nor in the astragalus. These bones were removed from a lad aged 14 years.

Specimen 38. (No. 1888). *Osseous ankylosis of tibia and astragalus.*—Tibia is rough, thickened, dense, and much deformed, having obviously been

the seat of acute necrosis with subsequent chronic inflammatory disease in early life. The astragalus, which is of natural size and shape, is firmly united by bone to the tibia along the posterior four-fifths of its articular surface, the anterior fifth remaining free and distinct. The line of junction between the tibia and astragalus is just traceable, owing to the slightly greater density of the cancellous tissue at that line. At the anterior part of the line of junction between the two bones the cancellous tissue is very dense, being continuous with dense tissue both in the tibia and in the astragalus (see Fig. 22). Where the joint surfaces are free and un-united, each bone is covered by its articular plate, and the surfaces are closely approximated, as if the cartilages had undergone more or less complete absorption.

Fig. 22.—Longitudinal section of tibia and astragalus which are united by bone (nat. size).

It may here be noted that when, for example, the tibia, especially the lower half, is the seat of acute necrosis the ankle joint is usually found to present the following changes. The synovial membrane is thickened and very red, and at each available place it is growing or has grown over the cartilage, thus replacing the surface layers of the articular cartilage to a variable extent. Extension of this would cover the cartilage with synovial membrane, and at the same time replace it so that at last the cartilage would be removed entirely and the two articular surfaces joined together by connective tissue which may become converted into bone.

(*d*) *Bony Ankylosis of Joints after Injuries.*

Stiffness of joints after injuries such as severe contusions; after fractures of the articular ends of the bones, whether the fracture enters the joint or not; and after the separation of epiphyses, is common enough; but usually this is the result of changes that take place outside the joint, and only in rare instances is it due to the formation of fibrous or other connections within the joint itself and between the articular cartilages. This variety of ankylosis more or less complete was, as I mentioned in the introduction, known to the Greeks, and its occurrence was especially guarded against. The true bony ankylosis of the joints in the limbs occurring simply as the result of injury, and without suppuration in the joint, must be of very rare occurrence, although it is frequently met with in the joints and between the arches of the vertebral column. I do not know of any example of such a condition, but reference is made to one by Cruveilhier.[1] It is, how-

[1] Cruveilhier, "Anat. Path." liv. ix. pl. v. figs. 1 and 2. The right temporo-maxillary articulation of an old woman who, when a child, received a blow on that side of the face. It appears that there occurred complete bony ankylosis. Mr. Howard Marsh tells me he remembers seeing such a case some years ago in his own practice.

ever, not uncommon to find after fractures at the lower end of the tibia and fibula a complete osseous union of the two bones, by the formation of bone across the inferior tibio-fibular joint. In this joint, it will be remembered, the tibia and fibula are mainly held together by a strong fibrous (interosseous) ligament, there being no joint or synovial cavity between them.

Fig. 23.—Transverse section of lower ends of tibia and fibula united by bone (nat. size).

Specimen 39 (No. 1421d). *Tibia and fibula.*—Direct fracture of both bones, 2 in. above the ankle joint. Fragments united with but little deformity. The lower tibio-fibular articulation is entirely obliterated, the two bones being firmly united by bone which is cancellous in structure (see Fig. 23). The articular end of the fibula is uneven, as if some change had taken place in it, but that of the tibia is natural. It would appear that in consequence of the disturbance produced by fracture of both bones immediately above, ossification had taken place in the interosseous ligament of this joint.

(*c*) *Bony Ankylosis in Disease or Injury of the Nervous System.*

Bony ankylosis undoubtedly occurs after arthritis in disease of the nervous system, as was first pointed out by Charcot ([25]).

In the condition known as the "tabetic foot" it not unfrequently happens that, not only is there disease of the inter-tarsal joints similar to that met with in other joints in tabes dorsalis, but there actually occurs bony ankylosis in one or more joints in the foot. Several examples of bony ankylosis of the tarsal bones in locomotor ataxia have been reported in France, and among them is one by Boyer ([26]). Charcot, it may be remembered, attributed all trophic lesions taking place in tabes to the result of disease of the nerve cells in the anterior horn of grey matter. During recent years, however, it has been maintained by French observers, especially Pitrés and Vaillard, that the joint and bone lesions in locomotor ataxia are the result of structural changes in the peripheral nerves; and that, for example, when spontaneous fractures occur there is almost invariably neuritis of the nerve supplying the fractured bone, and that there is no change in the cells of the anterior cornu of the grey matter in the area corresponding to the peripheral lesion. Consequently, these latter observers regard the trophic lesions of locomotor ataxia as due to peripheral neuritis in addition to the lesion in the posterior column of the cord, rather than to disease of the cells in the anterior horn of grey matter. In favour of such a view is the following and, as yet, solitary instance of bony ankylosis subsequent to injury of a peripheral nerve.

After injury to the peripheral nerves.—Mr. Bowlby ([27]) in his work, "Injuries and Diseases of Nerves," p. 53, gives an account of the joints of a hand eighteen months after division of the median nerve at the wrist joint. He says: "The finger joints were one and all stiffened. On opening those of the middle finger, the capsules were found to be thickened, and the cartilaginous surfaces of the most distal joints united by fibrous tissue. The terminal joint of the ring finger was firmly ankylosed, the union being by bone, and so firm as only to yield to cutting instruments." This is, so far as I am aware, the only example hitherto recorded of bony ankylosis supervening upon arthritis of nerve origin.

(*f*) *Ossifying Arthritis.*

The term ossifying arthritis is here used to denote a variety of bony ankylosis, which not unfrequently affects the joints of the hands and feet; it may also affect other joints of the body, as I will later show. This variety of arthritis occurs without suppuration, and although it may be found associated with rheumatoid arthritis, yet it is distinct from it in the changes that occur in the joint structures and in its ultimate result. It is probable that this ossifying arthritis is allied to, if not identical with, that which takes place under natural conditions in the terminal joint of the little toe of persons of middle age, and also to that which occurs between the articular processes of the vertebræ in tubercular disease of the bodies, after fracture-dislocations, and in the spines of elderly persons. The following are selected from a series of specimens in the Museum, and it seems to me they show pretty well not only the results of this disease, but also the processes by means of which those results are obtained:—

Specimen 41 (No. 1926). *Lower end of left radius and ulna, carpus and metacarpus.*—In this specimen the three bones of the first row of the carpus are fused together, but the remaining carpal bones, though some of them show signs of disease, are free and distinct. The articular surface of the lower end of the radius is remarkably pitted and uneven; some of these pits are as much as one-sixth of an inch in depth, and into them fit small projections from the upper surfaces of the scaphoid and semilunar bones, which surfaces are altered in like manner. Accordingly, when the bones of the radio-carpal joint are placed together (opposed), they so fit one another that movement between them would be impossible. There is no eburnation of any of these articular surfaces. The lower end of the ulna is enlarged by marginal growth of new bone, but the articular surface shows only slight structural change. The scaphoid and semilunar bones are completely fused, but there still remains on the exterior a line indicating the separation between the semilunar and the cuneiform bones. The outer part of the upper surface of the semilunar and that of the cuneiform are somewhat dense and worn down, evidently by their movements upon the ulna, supination and pronation being uninterfered with. The concavity formed by the first row of carpal bones has its articular surfaces changed in much the same manner as are the upper, but not in so marked a degree. In the distal row of carpal bones, which are all separate from one another, only the head of the os magnum requires notice. This

is somewhat reduced in size and somewhat coarsely pitted, but not dense and polished in any part. The carpo-metacarpal joints are unaltered and natural.

Specimen 42. *Carpus, and second, third, and fourth metacarpal bones of left hand.*—All the bones of the carpus, with the exception of the pisiform bone, are so fused together as to form one single piece; and to this mass are fused the bases of the second, third, and fourth metacarpal bones. On the exterior there is no indication of the pre-existence of joints, nor indeed is there in section any trace of junction (see Fig. 27). The superior articular surface of the scaphoid is enlarged by growth at its margins, and throughout the greater part of its extent it is perforated by minute round holes, but in one small area the surface is eburnated. The upper articular surfaces of the semilunar and cuneiform bones are in a similar state, and so is the distal articular surface of the unciform for articulation with the fifth metacarpal; but the surface of the trapezium for articulation with the metacarpal bone of the thumb is smooth, unaltered, and natural. In the section passing from before backwards through the scaphoid, trapezoid, and the base of the second metacarpal no trace of the junction of these three bones can be seen, the cancellous tissue of all being directly continuous (see Fig. 24).

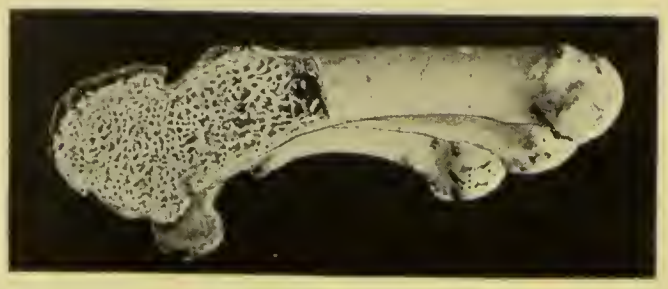

Fig. 24.—Longitudinal section through carpus and base of second metacarpal bone of left hand. Fusion of scaphoid, trapezoid, and second metacarpal bones (⅔ nat. size).

Specimen 43 (No. 1813). *Right radius and ulna, carpus and metacarpus.* Moist specimen.—The radio-carpal and the radio-ulnar joints show the changes commonly observed in chronic rheumatoid arthritis, which are, eburnation of the bone, thinning and fraying of the articular cartilages and the presence of multiple polypoid growths on the inner surface of the synovial membranes.

The bones of the carpus, with the exception of the pisiform and unciform, together with the bases of the second and third metacarpal bones, are so fused as to form one piece of bone, and the joints are completely obliterated, their places being taken by cancellous bone tissue. The joint between the cuneiform and the scaphoid on the one hand, and that between it and the unciform on the other still exist, and in all probability they indicate the kind of changes, in an early stage, through which the ankylosed joints passed. The bones are closely approximated, and the opposed articular cartilages have completely disappeared, so far as the naked eye can discover, and their place is taken by fibrous tissue. Although the articular cartilage is replaced, still the joint cavity, a mere chink, remains.

On separating the cuneiform it is seen that the joint surfaces, though practically denuded of articular cartilage, are smooth, and are connected with those of neighbouring bones by numerous small, delicate, fibrous bands. In the joint between the cuneiform and the scaphoid these delicate fibrous connections are more marked, and so they are in the joints between the unciform and the bases of the fourth and fifth metacarpal bones. Under the microscope, the following are the chief changes to be observed. Where the joint cavity still remains, the articular surfaces of the bones are found covered (1) by a thin layer of altered articular cartilage, (2) by a layer of cellular connective tissue, or (3) it may be bare, the bone itself exposed. The greater part of the

joint surfaces are usually covered by a thin layer of articular cartilage, which, it may be noted, can hardly be detected by the naked eye (Plate XXIX. Fig. 1).

Where the articular cartilage remains, it is usually found reduced to a thin layer. In the superficial layers the cells are numerous and rather large, and the intervening matrix is fibrillated in a direction parallel to the free surface, as if the superficial layers of the cartilage, before they disappear, undergo a transformation into fibrous connective tissue. The deeper layers of the articular cartilage remain unaltered, except that the cells are proliferated, and are not usually arranged in columns perpendicular to the free surface, as under normal conditions (see Plate XXIX. Fig. 2). Here and there the cells near the free surface are large with round nuclei and with granular protoplasm, and many of them lie free on the surface; this gives the impression that they first proliferate, then grow large and granular, and ultimately disappear into the joint cavity. It seems probable that the articular cartilage is in this manner reduced in size, until at last it quite disappears, leaving the subjacent dense bone exposed. In one place only I noticed that the remaining articular cartilage showed changes precisely similar to those seen in rheumatoid arthritis, namely, proliferation of the cartilage cells and the fibrillation of the matrix in a direction perpendicular to the free surface. The bone subjacent to the thinned and altered cartilage is for a short distance much condensed, or sclerosed, the trabeculæ being thick and the spaces small. In the spaces near the joint surface there is only a small amount of fibrous connective tissue with blood vessels, but further away the spaces are larger, and in them the connective tissue is more cellular; whereas deeper still the bone is like natural cancellous bone, the trabeculæ thin and the spaces large and filled with blood vessels and large fat cells (see Plate XXIX. Fig. 1). At one point union between the two opposed articular surfaces, though incomplete, can be seen (Plate XXIX. Fig. 3). The two dense layers of bone are seen closely approximated, in places with a slit between them, and in others quite fused.

Specimen 44 (No. 1905c). *Bones of right foot, phalanges of four outer toes missing.*—All the bones of the tarsus are firmly ankylosed to one another. On the exterior of the bones there is a considerable amount of new bone in the form of ridges and spicules, and especially is this the case at the lines of the junction of the separate bones, and where there are grooves and ridges for tendons. The os calcis particularly is covered by spicules of new bone. The upper articular surface of the astragalus appears normal.

The tarso-metatarsal joints are not ankylosed, but the articular margins on each side of the several joints are thrown up into irregular ridges or buttresses, the opposed surfaces of which are uneven, as if they were, in the first state united by fibrous tissue. The first metatarso-phalangeal joint is also ankylosed, and to the under surface of the metatarsal bone the two sesamoid bones are firmly united; the big toe is deflected outwards (see Plate XXX. Fig. 1).

Specimen 45 (No. 1905b). *Tarsus and metatarsus of left foot.*—All the bones of the tarsus are ankylosed by bone to one another and to the basal extremities of the metatarsals. On the exterior there is no evidence of any of the lines of the intertarsal joints, except that there is much new, somewhat finely-spiculated bone forming a sort of ridge where the joint should be. These ridges are especially seen at the line of the mid-tarsal joints and where the metatarsal bones join one another and those of the distal row of tarsal bones. On the under surface of the foot, which has a good arch, there is also a good deal of new bone formed in ridges and in spicules.

The distal end of the first metatarsal bone is expanded, especially to the outer side, and the surface almost in its entirety is coarsely pitted, but is not at any part dense and eburnated. The distal end of the fifth metatarsal is similarly altered (see Plate XXX. Fig. 2). The free articular surfaces of the

second, third, and fourth metatarsals, and the upper articular surfaces on the astragalus for articulation with the tibia and fibula, are quite natural. In an antero-posterior section, passing through the middle of the astragalus and the first metatarsal bone, it will be seen that the bones are so connected as to form one single, rigid piece. The astragalus is united to the os calcis at the margins of the articulation and partly at the interosseous ligament, the joint cavity in its central part being free and natural. The astragalus is united to the scaphoid by a bridge of cancellous bone at the upper part of the joint, and the lower end of the scaphoid is united to the sustentaculum tali of the os calcis by a bridge of bone in the position of the inferior calcaneo-scaphoid ligament. The greater part of this—the astragalo-scaphoid—joint is natural, except that the articular surfaces are unduly approximated to one another. The scaphoid, internal cuneiform, and the first metatarsal are so much blended together that there only remains just the central parts of the joints to indicate their former existence, and this is a narrow slit bounded on each side by an articular plate of bone. The cancelli of these three bones are, at the peripheral parts of the joints, directly continuous with one another (see Plate XXX. Fig. 3). The bony ankylosis has in this first taken place at the periphery, and then gradually extended towards the middle of the joints; and while this was taking place, the articular plates became approximated to one another, so as to diminish the space that would be left by the disappearance of the articular cartilage according to the process above described in the carpal bones.

Specimen 46 (No. 1905d). *Tarsus and metatarsus of left foot.*—The scaphoid, the three cuneiform, the cuboid and the bases of the three inner metatarsal bones are ankylosed to one another. There are ridges of comparatively smooth bone over the lines of junction of the several bones. At the adjacent articular margins, between the astragalus and scaphoid, there is much new bone which is spiculated in character; as there is also at the articular margins of the calcaneo-cuboid and the calcaneo-astragaloid joints. In these joints the articular surfaces are, however, intact and natural. The distal articular surfaces of the first and second metatarsals are slightly expanded, and that of the first is coarsely pitted, but not in any part dense and eburnated. In a longitudinal section passing through the middle of the astragalus and the metatarsal bone of the big toe, it is seen that the scaphoid and internal cuneiform bones are united at their peripheral parts, but not in the middle where the two bones are distinct, though closely approximated; the internal cuneiform and the base of the first metatarsal are also united to one another, but only at their peripheral parts. Near the upper part of this joint cavity delicate trabeculæ of bone may be seen extending from one surface to another across the joint cavity.

From the account given of the preceding specimens, we may draw the following conclusions:—

1. That the ossifying arthritis probably commences by the formation of continuous but finely-spiculated marginal growths of bone at the articular margins of the bodies; these bony growths are not covered by an extension of the articular cartilage, as in rheumatoid arthritis (lipping).

2. That these marginal ridges of bone grow towards one another and ultimately fuse, bridging over the joint cavity and firmly uniting the bones.

3. That while these changes are taking place on the exterior of the bones, the articular ends become approximated, owing to thinning

of the articular cartilage, which after a time completely disappears, leaving the opposed bones to grow together and become united across the joint cavity.

4. That when union has taken place across the joint cavity it does so from the periphery central-wards, and when there is complete fusion of the two bones then the external ridges of bone tend to diminish and to ultimately disappear, leaving the external surfaces of the bones pretty smooth and even.

5. That some articular surfaces become expanded and remarkably pitted without becoming dense and eburnated, and that opposed surfaces are so changed that the pits of the one surface receive the elevations of the other, and thus lock the bones and prevent movement.

6. The thinning of the articular cartilage takes place by the transformation of the most superficial layers, that is at the free surface, into a horizontally fibrillated tissue containing numerous cells, which doubtless cause ultimate absorption of the matrix, and then fall free into the joint cavity, disintegrate and disappear.

7. Immediately beneath the articular cartilage undergoing the above changes the bone is very dense, as it is in a slowly growing part, and by its growth the joint cavity is doubtless encroached upon, and then gradually obliterated; ultimately the two joint surfaces coalesce, the dense tissue at first formed being in time replaced by cancellous bone.

It will be observed that in no particular does this joint affection correspond with that seen in rheumatoid arthritis or in gout. It may, however, be held that the marginal growths seen in this ossifying arthritis are similar to the "lippings" in rheumatoid arthritis; but a careful examination of the two changes will not fail, I think, to show that the marginal growths that occur in the former disease arise independently of the articular surfaces, and are not covered by articular cartilage; whereas in the latter (rheumatoid arthritis) the "lipping" is, as it were, a direct extension of the articular end of the bone, the superjacent articular cartilage extending to an equal, or almost equal degree. Indeed, it may be said that in ossifying arthritis the marginal growth of bone takes place into the surrounding connective tissue—ligaments especially—and that once these structures are rendered rigid the joints themselves tend to become obliterated from the periphery towards the centre.

(*g*) *Under Uncommon Conditions.*

1. *In Flat Foot.*—The formation of marginal outgrowths of bone from some of the tarsal bones, especially those bordering the mid-tarsal joint, is well known in extreme cases of flat foot. Such growths doubtless occur to prevent the further falling of the arch, and they

are usually joined by fibrous connective tissue. Under exceptional circumstances they may become united by bone, as in the following specimen :—

Specimen 47. *The left foot with lower ends of tibia and fibula.*—The foot is quite flat, and the os calcis is strongly rotated outwards and drawn upwards, the tip of the external malleolus having come into contact and formed with it a false joint, as is not unfrequently the case in extreme examples of this condition. There are large plate-like outgrowths of bone on the adjacent articular margins of the bones of the mid-tarsal joint, which plates were during life united by fibrous tissue, but the two joints are free. The joint between the astragalus and the sustentaculum tali of the os calcis is obliterated, and the two bones are here so united to one another that they appear like one single piece ; in the astragalo-calcaneal joint the margins have in one place grown together, but are not yet united. In all probability the union begins at the periphery by means of the fusion of marginal growths, and then it extends through the entire joint cavity as in ossifying arthritis.

2. *In Leprosy.*—The fusion of bones following their destruction and absorption in leprosy is often very remarkable. An example of this is to be found in the following specimen, sent to the Museum from Trinidad by the late Dr. Beavan Rake :—

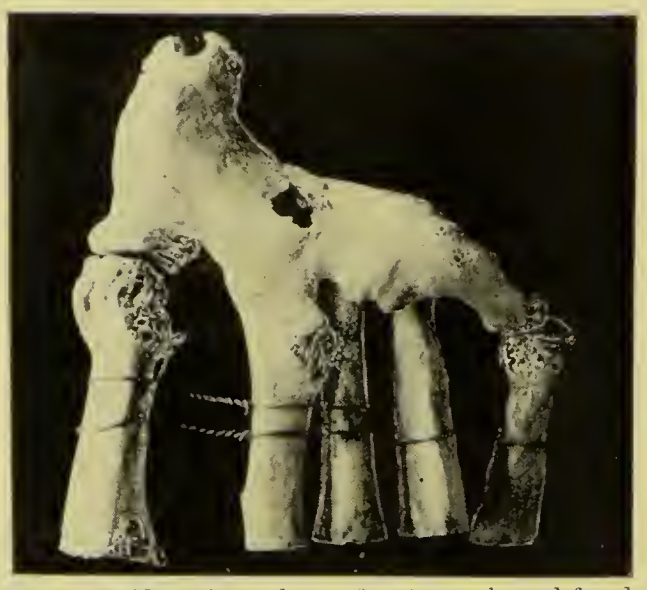

Fig. 25.—View from above of metatarsals and fused phalanges of the toes, from a foot typically affected with leprosy.

Specimen 48. *Phalanges and metatarsal bones of right foot.*—The bones of all the phalanges of the toes are fused together into one irregular mass of light bone, to which the anterior ends of the second and third metatarsals only are fused. The bones are exceedingly light, and the distal end, as well as the shaft of the first metatarsal, is much excavated (see Fig. 25).

3. *In Multiple Hereditary Exostosis.*—In cases of multiple hereditary exostosis, a few examples of which have been recorded, it is not unfrequent to find that the inferior ends of the tibia and fibula are completely united for a short distance, the cancellous tissue of the one being directly continuous with that of the other. The following well illustrates this condition :—

Specimen 49. *Lower end of tibia and fibula removed by amputation from a man who had multiple exostosis.*—The lower ends of both bones are slightly curved outwards, and the fibula is much thickened. For $2\frac{1}{2}$ in. the two bones are fused together, the cancellous tissue of the one being continuous with that of the other. This involves the inferior tibio-fibular joint (see Fig. 26). There is a similar specimen in the Musée Dupuytren.

Ankylosis of the Lower Halves of the Tibia and Fibula by Ossification of the Intervening Interosseous Membrane, and of the Ligament of the Inferior Tibio-fibular Joint.

The partial replacement of the interosseous membrane between the tibia and fibula by bone is commonly met with in cases where the leg

Fig. 26.—Transverse section of lower part of right tibia and fibula, showing complete union of the two bones and complete obliteration of the inferior tibio-fibular joint.

has been the seat of a chronic ulceration, associated with long-standing œdema of the soft structures. But the actual conversion of the membrane into bone, so as to firmly unite the tibia and fibula, must be of rare occurrence. An example of such a condition has recently been added to the Museum, and the description of it is as follows:—

Specimen 50.—The right tibia and fibula are united for 3–4 in. of their lower ends. The union is effected below by thick bridges of bone extending from the fibula to the tibia, both behind and in front of the inferior tibio-fibular interosseous ligament which remains unossified. Above this the union is by a thick plate of bone in the position of the interosseous membrane. Both tibia and fibula are covered with many small and short spicules of bone, which are evidently ossifications in the tendons of muscles, and these are especially marked on the oblique ridge of the tibia.

BIBLIOGRAPHY.

1. Hippocrates, ... "Chirurgie d'Hippocrate" (Petrequin).
2. Galen, ... "Opera," Venet., 1586.
3. Ambrose Paré, ... "Œuvres complètes," par Malgaigne, Paris, 1840.
4. Bernard Connor, . . . *Phil. Trans.*, London, 1700, vol. iii. p. 293; also, "De Stupendo Ossium Coalitu," Oxford, 1695.
5. Müller, ... "Diss. de Ancylosi," Ludg., 1707.
6. Büchner, ... "Diss. de Ancylosi," Erford, 1743.
7. Heister, ... "System of Surgery," London, 1759.
8. Paul, ... "Diss. de Ancylosi," Strasburg.
9. Van de Wympresse, . . "Diss. de Ancylosi Singulari, etc.," Ludg. 1783.
10. Murray, ... "Diss. de Ancylosi," Upsala, 1787.
11. Sandifort, ... "Exercitationes Academicæ," 1783.
12. Cloquet, ... "Dict. des. méd.," Paris, 1833, 2nd edition.
13. Cruveilhier, ... "Anat. Pathologique," tome i., Paris, 1835–42.
14. Wickham, ... "A Practical Treatise on Diseases of the Joints," Winchester, 1833.
15. Little, ... "Ankylosis or Stiff Joints," London, 1843.
16. Marsh, Howard, . . . *Brit. Med. Journ.*, London, Nov. 2, 1895.
17. Virchow, ... "Untersuch. ueber die Entwick. des Schädelgrundes, etc.," Berlin, 1857.
18. Rokitansky, ... "Pathological Anatomy," vol. iii. *Sydenham Society Translation*, London, 1849–52.
19. Schiffner, ... *Virchow's Archiv*, 1878, Bd. lxxiv. s. 320.
20. Humphry, ... "On the Human Skeleton," Cambridge, 1858.
21. Naegélé, ... "Das Schräg verengte Becken, etc.," Mainz., 1839.
22. Robert, ... "Des vices congenitaux de Conformation des articulations," Paris, 1851.
23. Wagner, ... "De Ancylosi Ossium Pelvis," Heidelb., 1818.
24. Annandale, ... "The Malformations, Diseases, and Injuries of the Fingers and Toes," Edinburgh, 1865.
25. Charcot, ... *Arch. de neurol.*, Paris, 1882.
26. Boyer, ... *Rev. de méd.*, Paris, 1884.
27. Bowlby, ... "Diseases and Injuries to Nerves," London, 1889.

DESCRIPTION OF PLATES XXIX. AND XXX.

Plate XXIX.

Fig. 1.—Section of the articular cartilage and subjacent bone of one of the carpal bones in ossifying arthritis. (*a*) Cartilage; (*b*) dense subcartilaginous layer of bone; (*c*) cancellous bone with large spaces containing numerous fat cells. (×80.)

Fig. 2.—Section of cartilage seen in Fig. 1. (*a*) Superficial layer of articular cartilage with its matrix fibrillated in a direction parallel to the free surface and with an uneven free edge; (*b*) deeper layers of cartilage which are more or less natural, though cells are arranged singly and not in groups running at right angles to the free surface. (×350.)

Fig. 3.—Section of a part where two carpal bones are in process of becoming united with one another across what was originally the joint cavity. (*a*) The line of the joint; (*b*) process of one bone interlocking with the other bone; (*c*) dense bone near the joint surface. (× 80.)

Plate XXX.

Fig. 1.—Bony ankylosis of the tarsal bones and of the metatarso-phalangeal joint of the big toe of the right foot. ($\frac{2}{3}$ nat. size.)

Fig. 2.—Anterior extremity of first metatarsal bone, showing remarkable pitting of the surface. (Nat. size.)

Fig. 3.—Mesial section through the tarsus and the first metatarsal bone. (*a*) Os calcis; (*b*) astragalus; (*c*) scaphoid; (*d*) int. cuneiform; (*e*) first metatarsal bone. ($\frac{2}{3}$ nat. size.)

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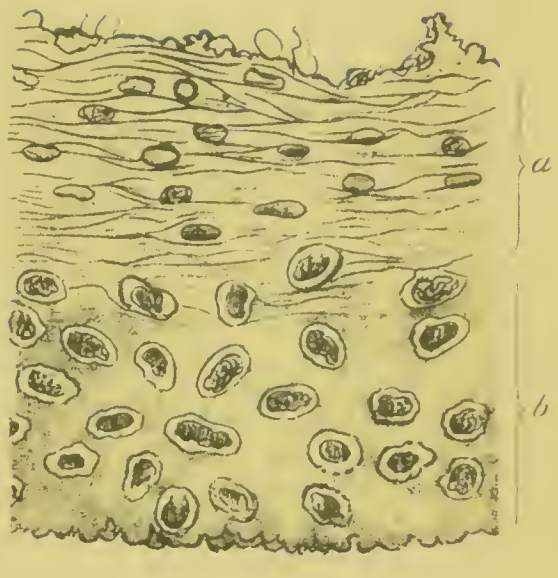
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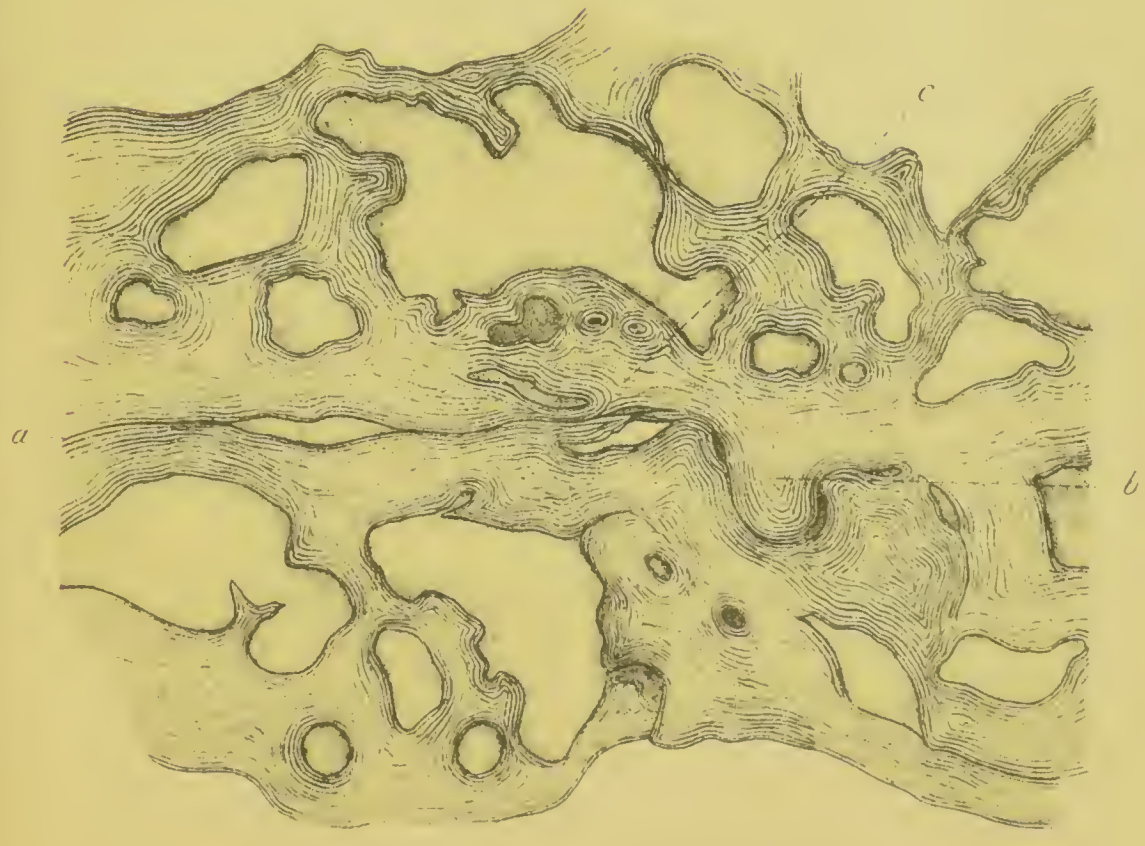
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UNIVERSAL BONY ANKYLOSIS, OR ARTHRITIS OSSIFICANS.

UNIVERSAL BONY ANKYLOSIS, OR ARTHRITIS OSSIFICANS.

By Joseph Griffiths, M.A. (Cantab), M.D. (Edin.), F.R.C.S. *Late Assistant to the Professor of Surgery in the University of Cambridge, Surgeon to Addenbrooke's Hospital, and Additional Examiner in Surgery, University of Cambridge.*

I propose to describe a diseased condition, which, owing to its rarity, and to its resemblance to other allied and well-known diseases, has hitherto been regarded as a variety of that great class—the rheumatic diseases.

From time to time during the present century a few cases have been observed and described in Europe and in America; but these cases have been regarded either as curiosities or as peculiar instances of chronic rheumatism, of rheumatic gout, or of gout itself. In such cases the joints become stiff, and this stiffening may end in rigidity, almost every joint in the body being involved, when the term universal ankylosis is, indeed, an appropriate one.

Some five or six years ago I was invited by Mr. Balding of Royston to see a man whom he has had under his care, on and off, for many years. This man, whose case is the first herein described, has suffered for a long period, indeed for the greater part of his life, from bony ankylosis of all the chief joints of his body; and now his skeleton forms almost one solid piece of bone, almost all the joints being stiff and rigid.

Since, I have had the opportunity of observing and noting the progress of three other cases which, I think, are of interest, and which will serve to illustrate the disease as to its different types, its progress, and its termination.

Not only has this malady a distinctive clinical course, but it has also a distinctive morbid anatomy, the joints attacked being affected in a manner different from that seen in already described and known joint diseases.

Arthritis ossificans, as I would call this disease, is characterised by one essential feature, namely, that the joints attacked—it is true, not quite without exception—become obliterated, and the articular ends of the bones grow together: in short, the bones forming the affected joints become fused with one another, so that the cancellous tissue of

the one becomes directly continuous with that of the other, without any trace of separation across what was originally the joint cavity.

This disease usually begins in the early years of adult life; the ages at which the disease has been observed to commence, in the reported cases, varying from 22 months to 34 years; the majority, however, being attacked between the twentieth and thirtieth years.

It is more common in men than in women: out of 18 instances 4 only were in women.

It is slow in its progress, being subacute or chronic, and it takes months, or even years, to involve and fix all, or, at any rate, the greater number of the joints in the body. It does not, like acute rheumatism, usually attack a number of joints simultaneously, but it involves one joint first, then spreads, as it were, to other joints, often attacking the joints of a limb in succession; for example, from the hand to the shoulder. In the chronic cases it creeps on, involving the joints insidiously, with the fixed purpose of obliterating their cavities and causing union which may indeed be best spoken of as a fusion or welding of the articular ends.

In one of the cases (Case 3), in which the disease ran a subacute course, a pretty clear account of the mode of onset, progress, and ending of the disease is given by the patient.

Briefly, there occurs in the subacute form, swelling, fixation (a pronounced feature), and pain in the joint. These symptoms persist for some weeks, or even months; all the symptoms then gradually subside, leaving the joint, usually without any deformity of the articular ends, painless and fixed in the position in which it was kept during the progress of the malady. When the joint first attacked is subsiding and becoming quiet, others, more or less in succession, are similarly attacked, each passing through precisely the same phases.

In the chronic form no swelling whatever of the affected joints usually occurs, but merely pain with increasing stiffness, leading on to absolute fixation.

Cases are met with where almost the whole, if not the whole, skeleton is thus joined into one rigid piece of bone; others in which the spinal column is the chief, if not the only seat of disease. These latter are already known under the name of *spondylitis deformans*, first given to them by Bardeleben. There are others still, in which the joints of the limbs only are involved, the disease being limited to the appendicular skeleton, just as in the cases of so-called spondylitis deformans, the affection is often, though not always, confined to the spinal column.

The morbid changes that take place in the joints during the progress of the disease in the subacute and in the chronic forms can only as yet be surmised; but the mode in which the ankylosis takes place in the chronic forms, and the state of the joint after the cessation of the diseased process, may be gathered from specimens of multiple anky-

losis in the hands and feet that are described in the preceding paper upon "Bony Ankylosis." These morbid changes that occur are, however, slight in comparison with the effect produced. For the fixation of the joints occurs without destruction and consequent deformity of the articular ends; so unlike in this respect, the results in tubercular and suppurative diseases which are so frequently associated with destruction and deformity of the joint-ends of the bones. Partial fixation of some of the joints, especially the knee and the metacarpo-phalangeal joints, is, however, liable to occur, though without destruction of the articulated ends.

I give, in the first place, the description of the four cases I have under observation; secondly, an account of two types of the disease, which are well illustrated by two skeletons in the Musée Dupuytren, photographs of which I have, through the kindness and courtesy of Dr. Pilliet, the director, herein reproduced; thirdly, a tabular form of the cases, hitherto reported under the titles "Universal Ankylosis" and "Spondylitis Deformans"; and fourthly, remarks upon the morbid anatomy, and upon the conditions under which the disease shows itself.

Case 1.—T. B., Royston, æt. 60 years, is a dark, healthy-looking but much emaciated man; he lies on his back with his legs slightly drawn up and his arms bent in front of his belly; he is rigid from head to foot, and, in consequence, quite helpless and incapable of doing anything for himself. He is so fixed that if one takes hold of one big toe and moves it from side to side the head also moves, but in the opposite direction; and he is, in consequence of fixation of his chief joints, easily managed and readily shifted from the bed to a chair by his sister who looks after him. He sits in the chair in a perfectly immovable manner; he is blind, very deaf, and incoherent and rambling in his talk. His pulse is good; breathing natural; his appetite moderate; bowels are now regular, though for many years past he suffered from constipation. Micturition normal; sleeps well for many hours day and night.

The skull, which is of normal size, is fixed to the vertebral column, so that it is not capable of being nodded; and the spine is almost straight and quite rigid from one end to the other. The lower jaw is distanced nearly a half inch from the upper, and in this position it is firmly fixed, admitting of no movement; but it is sufficiently open to allow of the ingestion of such food as minced meat, rice and milk puddings.

The ribs are rigidly fixed to the vertebræ behind, and in front to the sternum by ossification of their cartilages, so that the chest is a rigid barrel, and the respiration is purely abdominal. The right sterno-clavicular joint is fixed and immovable, and the articular ends of the bones appear to be slightly thickened and nodulated; the left is slightly movable, admitting, so far as I could determine, of a slight degree of circumduction. Both shoulder joints are firmly fixed; and in each arm the humerus lies along the side of the chest. The right elbow is fixed at a right angle, and all the bones are somewhat thickened, their outlines being somewhat obscured; the left elbow is fixed at an angle of 120° to 130°; in this, although there is hardly any thickening of the articular ends, the different bones are ill defined. Each forearm is strongly pronated. On both sides the radius and ulna, the carpal bones and the metacarpal bones, with the exception of the first and fifth on the left, are fixed to one another in their natural straight position, and are perfectly rigid. Both thumbs are bent inwards into the palm; in the right the terminal phalanx is

not fixed to the proximal one; but in the left all the joints are fixed and immovable, with the exception of the metacarpal bone, which is not fixed to the trapezium. The index finger of the right hand is deflected to the ulnar side over the remaining fingers which are flexed at the metacarpo-phalangeal joints, but hyper-extended at the first and at the terminal phalangeal joints. In the right index finger the first phalangeal joint is free, the terminal rigidly fixed. All the phalangeal joints of the third and fourth fingers are fixed, but those of the fifth are freely movable. The index finger of the left hand is sub-luxated forwards at the metacarpo-phalangeal joint, and the first phalanx is much shortened, but its joints are not fixed; the third, fourth, and fifth fingers are strongly deflected towards the ulnar side at their metacarpo-phalangeal joints which are fixed; and hyper-extended at the terminal joints which are movable. The muscles which are in relation to the movable joints are almost incessantly thrown into contraction, and especially is this the case when the parts are exposed to the air or handled. The left arm, owing to some circumductory movement at the sterno-clavicular joint, is frequently moved; the terminal phalanx of the right thumb, and the thumb and the fingers of the left hand, are likewise frequently moved. Both hip joints are fixed at an angle of 120° or thereabouts; both knees are closely approximated and bent to a right angle and rigidly fixed, the outlines of the bones being well defined. The skin over each patella is stretched, glazed and scabbed over, as if it had undergone superficial ulceration. Both feet are rigid, all the bones of the tarsus and the tibia and fibula being fixed to one another. There is some general thickening about the feet and ankles, the outlines of the individual bones being thus quite obscured. It is difficult to tell to what extent, if any, the metatarsal bones are fixed to the distal row of the tarsus in the right foot, but they are certainly fixed in the left. The left big toe is rigidly fixed to the first metatarsal bone, and its terminal joint is hyper-extended and rigidly fixed. There is some movement in the metatarso-phalangeal and in the inter-phalangeal joints of the remaining toes. In the lower extremities, as in the upper, all the joints that can be moved are frequently, if not incessantly, in motion when exposed.

History.—When 26 years of age he was quite well, and capable of moving about as other people, and was employed in London. Soon after this he came home suffering from what was supposed to be subacute rheumatism in several joints, and with pain in and along his spinal column. At the same time he suffered from an almost intractable gleety discharge, presumably a sequel to an attack of gonorrhœa. The condition of the joints affected, so far as can be ascertained, grew gradually and almost imperceptibly worse, yielding to no kind of treatment. He was intelligent, fond of reading, and could use crutches and feed himself for at least 14 years; after which time his arms became so fixed and his fingers so distorted, that he could neither use a crutch nor feed himself after many attempts at making ingenious mechanical contrivances. About this time his sight began to fail. Sixteen years ago he suffered from an attack of acute mania, from which he soon partially recovered, and in this state of partial recovery he has ever since remained.

Case 2 (Notes taken 12th August 1890).—E. N., æt. 23, a small, slightly bent, fair woman; pale and puffy round eyelids. Tongue clean, appetite good, bowels regular, and urine normal. Menstruation regular since Christmas, but absent previous to that for nearly 2 years. At this time the patient was under the care of Dr. Carver at Addenbrooke's.

The right elbow is bent at an angle of 150°, and firmly fixed; there is no swelling or thickening, and the bony points can be easily felt. The left elbow is similarly bent at an angle of 140°, and fixed; the bony points can with difficulty be made out, because there is some swelling. There is great limitation of movement in the right shoulder, but no external evidence of dis-

ease. Both forearms are pronated; both wrists are slightly bent (flexed) and quite fixed, but, beyond being prominent on the dorsum, they are unaltered. The carpo-metacarpal joint of the right thumb is swollen, and in it there is dry crackling on movement, which is very limited. The movements in the metacarpo-phalangeal joints of the four inner digits are limited, and are accompanied by dry and loud crackling noises. The first inter-phalangeal joint of the middle finger is swollen; and on movement, which is restricted, there is

Fig. 1.—Taken from a photograph of E. N., January 1896.

dry crackling. In the left hand the metacarpo-phalangeal joint of the thumb is fixed; the first inter-phalangeal joints of the fingers are swollen to a fusiform shape, and their movements, which are very limited, are accompanied by dry, crackling noises. The knees are slightly swollen, but movements are free. The tarsus of each foot, which is well arched, is fixed and rigid. Dr. Carver attempted to obtain movement in the elbows, but only succeeded in bending them, and thus improving their condition; while doing this, both elbows were broken, the union being bony.

6th January 1896.—The same patient 5½ years later.

General health good. Right shoulder joint firmly fixed. The humerus united to the scapula; no thickening in or around joint. Both elbows firmly fixed (humero-ulnar and radio-ulnar joints) at right angles. Forearms in semi-prone position. Both wrists also fixed—the carpus as one bone united to radius and ulna.[1] The second and third metacarpal bones of left hand firmly

[1] A skiagraph taken recently shows that there is complete fusion of the carpal bones with themselves, with the radius and with the metacarpal bones.

united to carpus; the carpo-metacarpal joint of thumb on same hand remains swelled, with limited grating movements; the first inter-phalangeal joint of index—the first joint affected—firmly fixed, admitting of no movement. In the right hand the first, second, and third metacarpal bones are firmly united to the fused and immovable carpus; and the first inter-phalangeal joint of the middle finger is swelled—the ends of the bones being large, and movements very limited.

In the spine the dorsal curve is exaggerated, but all the movements are present, though limited.

In the lower extremities the hip, knee, and ankle joints admit of some movement; but in the ankles it is often accompanied by dry crackling noises. In both feet the tarsal bones are fixed, and form, as in the carpus of each hand, one rigid bone, it being impossible to distinguish the outlines of the individual bones in either foot. In the left foot the first, second, third, and fourth metatarsal bones are rigidly united to the tarsal bones with which they articulate; and in the right the first, second, and third are similarly fixed, the fourth and fifth retaining their natural free movement.

History.—Two years before admission into Hospital (1888) she caught a severe cold, which was soon followed by a painful swelling of the first inter-phalangeal joint of the left index finger; after a time the pain ceased, and the swelling gradually diminished, leaving the joint stiff and immovable. Soon other joints became similarly affected, the wrists, the elbows, and the right shoulder, the left escaping. Each joint passed through exactly the same stages as the first inter-phalangeal joint of the left index finger, and almost every joint attacked, after some 3 or 4 months, quietly settled down and became rigidly fixed. After a year or so, both feet became swollen and very painful, rendering walking about quite impossible; and they, likewise, in their turn quieted down, both the swelling and the pain disappearing together, until at last she could again walk on them, as she does now, with comfort and ease. During all this time—a period of about 18 months—there was no appearance of the menses; but on the subsidence of active changes in the joints, this was re-established, and has been going on regularly ever since.

She says other joints besides those now fixed were at first affected, such, for example, as the temporo-maxillary joints, but these, with a few others, have recovered and escaped fixation.

Father and mother alive and well. Has 9 brothers and sisters; one brother, 22 years (1896), suffered from rheumatic fever at the age of 19 years; all the others quite well. Maternal grandfather is the only other relation known to have suffered from rheumatic affections.

Case 3.—E. S., 35 years, single, dressmaker, residing in Cambridge. She is fair, and moderately strong; tongue clean; appetite very small; digestion very indifferent, and there is troublesome constipation. Pulse quick and weak. Breathing, which is chiefly abdominal, is heavy and difficult on slight exertion; no cough. Requires but little sleep. Her back is strongly bent backwards, so that the cervical, dorsal, and lumbar regions form one single curve, most pronounced in the upper dorsal region; there is slight lateral curvature to the left in the lower portion of the lumbar part. The entire column, thus curved and slightly bent laterally, is rigidly fixed from one end to the other, any attempt at bending or rotating the spine being followed by ineffectual but easily observed contraction of the muscles that would be called into action to produce the given movement. Such muscles can be very clearly demonstrated in this condition. The head is carried on a projecting, almost horizontal, cervical spine, and it is not fixed to the spine, the nodding movement being present but very limited. The ribs are not fixed to the column, as they can be raised in deep inspiration. All the other articula-

tions, those of the lower jaw with the skull, and those in the limbs, are perfectly free and natural, showing no signs whatever of becoming fixed. In short, the spine only is fixed; at the same time it is much curved. Associated with this curvature and fixation of the back is a troublesome form of dyspepsia and constipation.

History.—Between 22 and 23 years of age, while working as a dressmaker in London and using the sewing-machine for many hours a day, she thinks she caught cold from often having damp and cold feet—the cold, she thinks, settled in her neck. She says that the back of the neck swelled, and became painful and stiff very soon after. This trouble gradually grew worse, and, in consequence, after a period of about 3 years, she had to give up her employment and return home. In 1889 she was under the care of the late Sir George Humphry at Addenbrooke's. At this time nothing much could be made out in her neck, except pain and stiffness, without any clear signs of actual disease. Nothing seemed to do her any good. Latterly her back has become more and more bent, and she thinks it is still getting worse. After much standing, sitting, or walking the whole back begins to ache. The condition has reached its present stage very slowly and insidiously.

Case 4.—Mrs. M.,[1] 36 years, widow, with two children, residing at Peterborough; now under the care of Dr. Walker, to whom I am indebted for the opportunity of having seen the patient. A dark, healthy-looking woman; tongue clean; appetite good and bowels regular; no cough; does not sleep well; urine normal. She lies on her back, with her body rigid, head fixed, and the knees drawn up. Often has great pain in the lower part of the back and in the joints that are becoming stiff.

The vertebral column is rigid from end to end; the head is fixed to the column, so that there is neither rotatory nor nodding movement. The mouth can only be opened to the extent of barely half an inch. The chest is rigid, and the breathing, even when of a forced character, is almost entirely abdominal. The right sterno-clavicular joint is rigidly fixed, admitting of no movement; the left, on the contrary, allows of free movement. The joints of the hands and arms are natural, with the exception perhaps of the right shoulder which is dry and creaks on movement. The right hip is slightly flexed and fixed, whether absolutely or not is difficult to determine. The right knee, which, owing to the flexion of the hip is necessarily kept in a bent state, is sometimes very stiff and painful. The right ankle and the joints of the foot are natural. The left hip is flexed and fixed, but I think there is still some movement in the joint. The left knee is in the same state as the right, that is, at times stiff and painful. The joints of the left ankle and foot are natural.

History.—Thirteen years ago, when 23 years of age, she suffered from pains in the back, which were considered to be lumbago and sciatica. These pains kept getting worse. Eight years ago she lost her husband, and, in consequence, took a small business in hand at which she worked very hard. Seven years ago her neck became stiff, and this she attributed to putting her hair up and catching cold from its exposure. The back then got stiff, and she gradually got worse. Three years ago, when Dr. Walker exhibited the case, before a meeting of the Cambridgeshire and Huntingdonshire branch of the British Medical Association, the back was rigid and the head fixed; but she could walk, though very bent, the bending being chiefly at the hip joints. Eighteen months ago the right hip got stiff and very painful, and about 6 months ago, the left hip became similarly affected. Power was lost in the right arm a year or two ago, owing, doubtless, to fixation of the sterno-clavicular joint, in which she had no pain. Thus almost all the joints affected became stiff and painful

[1] Notes of this case were taken in January 1896.

without any swelling, and gradually the movement in them became less and less.

Family history.—Father died at 72; mother at 38. One brother alive and well; two sisters; the eldest died about a year ago from carcinoma of the pylorus. No history of rheumatism, gout, or tubercle in the family.

Two Skeletons in the Musée Dupuytren.

Case 1 (*reported by Percy*).—This is the case of an officer in the French army who had served in three campaigns. At the age of 25 years he had an attack of gonorrhœa, having previously suffered from gout in the big toe. For some years gout and ophthalmia occurred alternately; otherwise he was quite well. At 34 (1786) several of his joints were attacked simultaneously, those of the feet, knees, and hips. After this the remaining joints in his body became stiff and rigid. At the age of 50 years he died, having subsisted on fluid nourishment for some years. The descriptive account of his skeleton, which was given by Percy to the Musée Dupuytren, is as follows:—

Translation of the Description given in the Catalogue of the Specimens in the Musée Dupuytren by Houel.

No. 715.—A skeleton, in which almost all the joints are ankylosed, with the exception of the right humero-radial and the right hip.

Head.—The sagittal suture is almost entirely obliterated. The temporo-maxillary articulations are fixed, and the occipital bone is fused to the first vertebra.

Vertebral column.—The vertebral column, which is straighter than natural, is slightly curved laterally, especially in the lumbar region. All the vertebræ are united by their bodies and by their articular processes. The fusion is less complete between the bodies of the sixth and seventh cervical, between the seventh and eighth dorsal, and between the fourth and fifth lumbar vertebræ.

All the ribs are fused with the vertebræ, and the first ribs are ankylosed in front with the sternum. The sternum forms one piece, and the xiphoid cartilage is ossified, and so are some of the costal cartilages.

Clavicle.—The inner ends of the clavicle are united to the sternum, and to the first rib. The outer ends are united to the acromion, but the coraco-clavicular ligaments are not ossified.

Upper extremities.—The upper ends of the humeri are ankylosed to the scapulæ in such a manner that the arms are strongly abducted and distanced from the sides.

Both elbows are ankylosed, but on the right side the humero-radial joint is free. The forearms on each side are pronated. The carpal bones are fused with one another, and to the radius on each side.

On the right side the first phalanges are luxated forwards upon the meta-carpals, the second are hyper-extended upon the first, and the terminal joints are flexed and fixed.

On the left side all the first phalanges are luxated forward and deviated to the ulnar side upon the metacarpals.

Some of the phalangeal joints are fixed, but not sensibly deviated.

Lower extremities.—The sacro-vertebral (iliac?) joints are ankylosed, and so is the inter-pubic; and the pubis is covered with spicules of bone from ossification in the attached tendons. The left hip joint is ankylosed, but the right is free, the head of the femur being worn, and received into a large acetabulum. The knee joints are sub-luxated, and fixed at a right angle.

The patellæ are fixed to the external condyle of the femur on each side.

The superior tibio-fibular joints are ankylosed, the lower are free. The ankle joints on both sides are fixed.

The disposition of the os calcis is remarkable, in that its hinder extremity

Fig. 2.—From a photograph of skeleton, No. 715, Musée Dupuytren. Right leg is, owing to subluxation and flexion at the knee, apparently much shortened.

is lowered, the anterior raised, and the anterior part of the foot is depressed and the foot pointed. In consequence, the arch of the foot is much increased. (The feet are in a position of slight equino-varus.)

Case 2 (No. 719).—*Portion of a skeleton, composed of the head, trunk, pelvis, and the upper end of the right femur.*—This skeleton, which is that of a man,

presents a considerable deformity of the vertebral column; there exist three lateral curves. The cranium, which is normal, is ankylosed to the column, and the odontoid process is absorbed.

The vertebral column shows first, from above downwards, an antero-posterior curve, with its convexity forwards, extending from the first to the seventh cervical vertebra; these vertebræ are ankylosed to one another by

FIG. 3.—From a photograph of specimen, No. 719, in Musée Dupuytren.

their bodies, articular processes, and laminæ. In the lower vertebræ only is the ankylosis between the bodies incomplete.

The dorsal region shows two curves. The one cervico-dorsal, with its convexity to the left, includes the two last cervical and the first seven dorsal vertebræ. All these vertebræ are ankylosed to one another by their bodies, articular processes, and laminæ. The fusion is less pronounced on the convex than on the concave side of the curve. The other curve, dorso-lumbar, has its convexity to the right, and involves the remainder of the column down to the sacrum. All the vertebræ are fused to one another. [In short, the spinal column is bent antero-posteriorly as well as laterally.]

List of Cases of Universal Ankylosis, or Arthritis Ossification.

No.	Name.	Age.	Sex.	Time Disease began.	Joints Affected.	Attributed Cause.	Result.	Reported by
1	...	22 to 23 months.	M.	...	Nearly all.	...	...	Deslandes, "Hist. de l'Acad. des Sci.," 1716.
2	...	67 years.	M.	...	Nearly all, knees exeepted.	Exposure.	Died of an aeeidental overdose of opium.	Gastellier, *Journ. de méd. chir. pharm. Grab.*, Maraschino, 1815.
3	...	46 ,,	M.	...	Nearly all.	Gonorrhœa.	...	*Ann. univ. di med. e chir.*, Milano, 1824, tome xxxii. p. 46.
4	T. R.	36 ,,	M.	28½ years.	Nearly all joints.	Exposure to damp eold.	...	Lyons, *Lancet*, London, 1831, vol. i. p. 27.
5	...	50 ,,	M.	34 ,,	Nearly all.	Fatigue.	Died at 50 years.	Perey, "Dict. des Seien. méd." tome iv. p. 245.
6	Unable to	obtain partieulars.	...	...	...	...	...	Larrey, *Presse méd. belge*, Bruxelles, 1837.
7	...	34 years.	M.	12 to 13 ,,	Nearly all.	...	...	Hurd, *Boston Med. and S. Journ.*, 1845, vol. xxxi. p. 81.
8	...	Old.	M.	...	Many joints, espeeially hands and feet.	...	...	Broca, *Bull. Soc. anat. de Paris*, 1849, tome xxiv. p. 70.
9	E. E.	30 years.	F.	19 ,,	Nearly all.	...	Died of typhoid at 30 years.	Wilson, *Med. Exam. Phila.*, 1856, vol. xii. p. 326.
10	G. E.	34 ,,	M.	30 ,,	Spine, right hip.	...	Died.	Fagge, *Trans. Path. Soc. London*, 1877, vol. xxviii.
11	J. A.	26 ,,	M.	18 ,,	Spine.	...	...	Sturges, *Trans. Clin. Soc. London*, 1879, vol. xii.

12	...	30 ,,	M.	27 ,,	Spine.	...	...	Clutton, *Trans. Clin. Soc., London*, 1883, vol. xvi. p. 232.
13	...	20 ,,	M.	8 ,,	Right foot, spine.	Injury to neck.	...	S. Paget, *Trans. Clin. Soc. London*, 1894, vol. xxvii. p. 271.
14	T. B.	60 ,,	M.	27 ,,	Nearly all.	Gonorrhœa.	...	Herein by Author, 1896.
15	E. N.	29 ,,	F.	21 ,,	Joints of arms and feet.	Severe cold.	...	Do.
16	E. S.	33 ,,	F.	21 to 23 ,	Spine.	Wet feet.	...	Do.
17	M.	36 ,,	F.	23 ,,	Spine, right hip.	Worry.	...	Do.
18	F. G.	44 ,,	M.	23 ,,	Spine, shoulders, hips, and costo-vertebral; other joints stiff.	Gonorrhœa, with hereditary tendency to rheumatism and nervous diseases.	...	A. Morison, *Trans. Clin. Soc. London*, 1889, vol. xxii. p. 10.
19	D.	...	M.	...	Spine and temp.-max. joints.	Injury to neck.	...	Guy's Hospital Museum Specimens, 1010 and 1070, 1825.
20	...	Fœtus at birth.	...	...	Unable to find	particulars.	...	Busch, "Geschlechtsleben des Weibes."

All the ribs are fixed in variable degrees of inclination on both sides; ankylosis is complete between their heads and the bodies of the vertebræ, also between their tubercles and the transverse processes. The sternum forms one single piece of bone. The sacro-iliac joints are ankylosed; so also is the symphysis pubis.

[The right hip-joint is also ankylosed. The left acetabulum is enlarged, and shows some of the changes seen in osteo-arthritis.]

There are two other skeletons showing universal ankylosis in the Musée Dupuytren. They, however, only show changes similar to those described in detail above. Of the one described by Professor Breschet there is no history of any kind; the other is the skeleton of an aged woman.

From the account of the cases observed by myself, and from the table of those previously reported by others (see pp. 478, 479), there can hardly arise any doubt but that the disease, hitherto regarded as spondylitis deformans, is in nature identical with that which I propose to call Arthritis Ossificans, and which has been known as Universal Ankylosis, etc. These two separate forms occur at the same period of life, and each runs a similar course.

In the *so-called* spondylitis deformans we find that the spinal column may undergo, during the progress of the disease, remarkable changes in its curves. The normal antero-posterior curve may become greatly exaggerated, especially in the cervico-dorsal region, and in addition a lateral curve of a more or less pronounced degree may arise. These marked changes in the curves of the spine are found to be mainly dependent upon the fact that the person, so long as the disease is confined to the column, is able to go about and attend to his or her duties.

In Case 3 this deformity is well developed, the scoliosis as well as the kyphosis being pronounced; and in Fig. 3, taken from a specimen in the Musée Dupuytren, these changes in the column are well illustrated. The spine even, if the person lies in the recumbent position, is liable to undergo some slight changes in its curves; for it becomes straighter with the head and neck held forwards, the effect of placing the head on a raised pillow; and there may be, as in Fig. 2, from another skeleton in the Musée Dupuytren, a slight lateral curve in the dorsal region. The deformity of the spine in the main, therefore, depends upon the habits of the patient. If he or she be able to go about, the deformity is liable to be great, if compelled to lie in the recumbent position it will be but slight.

The relation between this *so-called* spondylitis deformans and the kyphotic changes that arise in elderly people is probably a close one. In elderly people the spinal curvatures are doubtless, in many instances, the result of failure in muscular strength to maintain the column in its proper curves; but in a few cases it would seem that some painful structural changes in the spine precede the deformity and subsequent rigidity; in other words, the deformity seems, in these

latter, to be dependent upon arthritic changes in the various vertebral joints. As these arthritic changes usually lead to obliteration and bony ankylosis of the joints, and as ossification into the interosseous ligaments also occurs, it is more than probable that this affection in elderly people is more closely allied to arthritis ossificans than to arthritis deformans, rheumatoid, or osteo-arthritis.

In Case 4 and in the skeleton, Fig. 3, one or more joints in the appendicular skeleton are ankylosed, showing that the disease may in some instances, where it starts in the spine, spread to the joints of the limbs.

In Case 2 the disease is as yet confined to the joints of the upper extremities and of the feet, the spine remaining free.

Just as a group of joints may be involved, so I presume single joints may be; and as the disease may cease after attacking several joints, so it may be reasonably supposed to cease after attacking one only. In this manner we may account for the frequency with which specimens of osseous ankylosis of the carpal bones belonging to this type are to be found in different collections of morbid specimens.

Morbid anatomy.—As I have before said, the exact changes which take place in the subacute form have never been observed, nor indeed have those which take place in the chronic form, although the ultimate result in each is known. We may, however, by analogy assume that the structural changes to be seen in this disease are similar if not identical with those that I have described in connection with an ossifying arthritis of many joints in the hands and feet.

The conclusions arrived at from a study of such specimens is all I need give here. For a fuller account, I must refer to my preceding paper upon Bony Ankylosis.[1]

From the account given of the preceding specimens we may draw the following conclusions:—

1. That the ossifying arthritis probably commences by the formation of continuous but finely spiculated marginal growths of bone at the articular margins of the bodies; these bony growths are not covered by an extension of the articular cartilage as in rheumatoid arthritis (lipping).

2. That these marginal ridges of bone grow towards one another, and ultimately fuse, bridging over the joint cavity and binding the bones firmly together.

3. That while these changes are taking place on the exterior of the bones, the articular ends become approximated, owing to thinning of the articular cartilage, which after a time completely disappears, leaving the opposed bones to grow together and become united across the joint cavity.

4. That when union has taken place across the joint cavity, and it does so from the periphery central-wards, and when there is

[1] *Journ of Path. and Bact.*, vol. iv. pp. 284–337.

complete fusion of the two bones, then the external ridges of bone tend to diminish and to ultimately disappear, leaving the external surfaces of the bones pretty smooth and even.

5. That some articular surfaces become expanded and remarkably pitted, without becoming dense and eburnated, and that opposed surfaces are so changed that the pits of the one surface receive the elevations of the other.

6. The thinning of the articular cartilage takes place by the transformation of the most superficial layers, that is, at the free surface, into a horizontally fibrillated tissue containing numerous cells which doubtless cause ultimate absorption of the matrix, and then fall free into the joint cavity, disintegrate and disappear.

7. Immediately beneath the articular cartilage undergoing the above changes the bone is very dense, as it is in a slowly growing part, and by its growth the joint cavity is doubtless encroached upon, and then gradually obliterated; ultimately the two joint surfaces coalesce, the dense tissue being in time replaced by cancellous bone.

It will be observed that in no particular does this joint affection correspond with that seen in rheumatoid arthritis or in gout. It may, however, be held that the marginal growths seen in this ossifying arthritis are similar to the "lippings" in rheumatoid arthritis; but a careful examination of the two changes will not fail, I think, to show that the marginal growths that occur in the former disease arise independently of the articular surfaces, and are not covered by articular cartilage; whereas in the latter (rheumatoid arthritis) the "lipping" is as it were a direct extension of the articular end of the bone, the superjacent articular cartilage extending to an equal or almost equal degree. Indeed, it may be said that in ossifying arthritis the marginal growth of bone takes place into the surrounding connective tissue,—ligaments especially,—and that, once they are rendered rigid, the joints themselves tend to become obliterated.

Although it seems certain that the joint affection observed in these cases is distinct from other known joint affections, such as rheumatic arthritis and gout, yet it must be borne in mind that it is allied to these conditions, and that they may be found associated with it.

For example, in a case of arthritis ossificans, several joints may show those changes which are regarded as typical of rheumatoid arthritis or, it may be, of those which are known as gout. What determines the development of arthritis ossificans in one joint, rheumatoid arthritis or gout in another, is at present beyond our knowledge.

The point I would most emphasise is that the condition herein described as arthritis ossificans is distinct both clinically and pathologically from either rheumatoid arthritis in its various forms and ending in false ankylosis of different kinds, or the arthritis of gout with and without fixation of the joints involved.

Causes of Arthritis Ossificans.

With regard to the causes of this somewhat rare malady I may premise my remarks by saying that we know pretty definitely that certain joint-lesions have been, and can be produced by diseases of, or injuries to, the central and peripheral nervous systems.

Indeed, none now dispute that the malady known as Charcot's disease of joints results from definite sclerotic changes in the spinal column associated with, it may be, peripheral neuritis and setting up locomotor ataxia. The changes that arise in Charcot's joint disease are similar to but not identical with those seen in rheumatoid arthritis. Again, we know that division of a peripheral nerve may not only be associated with disease of the joints supplied by it but with actual bony ankylosis, as occurred in one instance described by Mr. Bowlby.

Although we cannot as yet refer this ossifying arthritis to any definite cause, nervous or otherwise, yet we can determine to some extent the conditions under which it occurs. It begins, as a rule, in early adult life, and may run its course in a few years, and when no vital organ is involved the patient may go on living on fluid nutriment for many years. We find that it is referred (1) to exposure to cold, wet, and fatigue; (2) to worry; (3) to attacks of gonorrhœa which, when subsiding, give rise to a subacute or chronic form of rheumatism; and (4) to injury. In one instance it was of congenital origin, and in another it must have occurred soon after, if not before birth, for the child at 23 months was rigidly fixed.

We may conclude, therefore, that arthritis ossificans may occur after an injury, after exposure to cold and wet, after prolonged worry, and after gonorrhœal infection. We do not as yet know whether some disease of the central nervous system altering the trophic processes in joints can give rise to this malady.

It may, however, with fairness be held that in the first case herein described there is associated with the ankylosis some disease of the central nervous system, as evidenced by the attack of acute mania from which the patient suffered some years ago and by his incomplete recovery therefrom.

It may also be that the causes, hitherto unknown, of rheumatic affections are capable of producing arthritis ossificans, but until these causes are determined with greater accuracy, nothing but what is hypothetical can be said regarding them.